THE ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XI. No. 9 SEPTEMBER, 1950

EDITORIAL

Engineers—Too Many or Too Few

UNLESS the number of engineering students increases, there is a strong probability that instead of a large surplus of engineering graduates, which has been rather widely prophesied, there will soon be fewer engineering graduates available than are needed annually by the national economy of the United States. This is the opinion of Henry H. Armsby of the American Office of Education. He reports that the Manpower Committee of the American Society of Engineering Education for the past several years has emphasized the fact that engineering is still a growing and expanding profession; that not only the total number of engineers, but also the ratio of engineers to total employment, has been steadily rising ever since employment statistics have been assembled. Many factors operate towards a continuation of this increase in the ratio of engineers to total employment. Among these are: the continually increasing need for engineering and research in industry and Government; the tendency for engineers to develop new processes and services which create needs for new kinds of engineers and technicians; and the growing tendency of employers to recruit men with engineering training for jobs which have not in the past been considered engineering jobs, but for which an engineering background is becoming more and more useful.

Simplification in British Industry

The group of industrialists which was appointed by the Anglo-American Council on Productivity, and which, a year ago, made an investigation into simplification in industry in the U.S.A., has now made an enquiry into the progress of simplification in Britain.

One of the most important facts brought to light was that methods of costing, where individual firms have a wide range of products, are, for the most part, inaccurate. Generally speaking, the true costs of small-run and special orders are not known. Except in the comparatively few factories where such orders are segregated, overhead costs are not allocated among products in their correct proportions. More accurate costing would result in the elimination of much needless and unprofitable variety.

Another important problem is that of reconciling demands from sales staff for new lines and increased variety with cost and production problems. The group emphasized the need for careful market research before the adoption of any new product, and also for an investigation into the suitability of the product for manufacture with existing skill and facilities. Wherever possible, the adoption of a new line should be followed by the dropping of an earlier one, so that the total number is kept constant. To carry out this policy, it is necessary for sales and production policies to be integrated at a high management level.

The group frequently found a misconception as to the effects of simplification on the consumer. There is no reason why simplification should result in lower-quality standards or inadequate choice. Greater concentration by a producer on a narrower range of types does not by itself imply less total variety. Each producer is still free to make his own selection of products, and the existence of consumer demand for any particular article will ensure its supply.

Other points discussed are the necessity for organization of surveys of the possibilities of simplification—and this, it is suggested, might be undertaken by the appropriate trade associations—the part played by the designer in simplification, and the requirements of export markets.

Farnborough Flying Display and Exhibition

A feature of the Flying Display and Exhibition at Farnborough this year has been the policy of encouraging membership among the British Commonwealth countries. The Society of British Aircraft Constructors has members in Canada, India and Australia. To Canada must go the credit for exhibiting the first gas turbine power unit of its own design and production.

On show was the largest number of new types of aircraft ever shown. Of the 58 aircraft exhibited, 30 were making their first appearance.

By now, the distinctive note of the gas turbine engine has become a familiar sound all over the world. The British Aircraft Industry has, in particular, put emphasis on the development of the gas turbine engine. Twenty-eight of the aircraft taking part in the Display were powered by either turbo-jet or turbo-prop engines. Some of these are experimental, others are about to go into operation with Service squadrons in a great variety of rôles; other types have been accepted as the standard equipment of over a dozen foreign Air Forces and are expected to remain standard for some years. On the civil side, the gas turbine engine stands ready to prove its worth on the airlines of the world.

U. S. A.

A Modern American Tube Mill

Special steel tubing, both seamless and welded, ranging in sizes from ½ in. to 9 in. o.d. can now be produced at the modernised Gary Works of National Tube Company, a United States Steel subsidiary. Most unusual of the new equipment is the No. 3 seamless mill, a push-button installation which can shunt pierced shells from the piercing mill in any one of three separate directions, depending on the type of tubing to be rolled. Three electric-weld tube mills are also part of the new installation, making possible the production of welded carbon steel tubes from ½ in. to 5 in. o.d. For the manufacture of stainless steel tubular products, all processing installations have been selected for closeness of control and for the production of a high-quality product.

No. 3 Seamless Mill and Facilities

THE No. 3 seamless mill is an automatic continuous seamless and Assel combination mill producing tubes in hot-rolled lengths of 45 ft in light-wall tubing and 25 ft in heavy-wall tubing. Sizes range from 1 in. to 3½ in. o.d.

There are two separate continuous lines of in-line heating chambers for heating rounds. Each consists of 27 chambers, 19 chambers being used to bring the cold rounds up to the desired temperature and eight to hold or soak them to ensure even heating.

The 27 chambers in each line are grouped into six separately controlled zones, either gas or oil fired. Tube rounds are charged cold at predetermined lengths and are cut to the required piercing mill sizes by hot saws at the end of each furnace line. The tube billets then enter the piercing mill, which is of the conventional Mannesmann type with the usual inlet and outlet troughs.

From this point the path of the pierced shell is determined by the type of tubing to be rolled. For small-diameter light-wall tubing, a mandrel bar is inserted and both mandrel and tube pass through the 8-stand continuous rolling mill. The bar is then removed and returned for the next tube while the rolled tube passes through the reheating furnace and on through the 12-stand reducing stretch mill.

The reheating furnace is a roll-down type with inlet and outlet water-cooled rollers. The furnace is 48 ft long inside with 3-zone control, equipped with furnace pressure, temperature and fuel controls.

Like the mandrel mill, the stretch-reducing mill is arranged with its successive stands located at right angles to each other, with each pair of rolls inclined 45 degrees to the floor level. The rolls of each stand have semi-circular grooves which alternately engage one side and then the other of the shell's circumference. By producing a speed differential between the successive roll stands, tension is produced in the portion of the tube between the stands. Delivery speeds run from 850 to 1700 fpm.

After leaving the stretch mill the finished tube passes across a cooling table to a multiple cold saw where it is cut into lengths as required. It then moves to the scales for weighing.

When rolling heavy-wall tubing the pierced shell, after leaving the piercing mill, by-passes the 8-stand mandrel mill and passes directly through the Assel mill. The mandrel bar is then removed and the tube passes on through the reheating furnace to the 12-stand sizing sinking mill. This mill is conventional with a common motor operating the gear-reduction drives and the line shaft. Again the tube passes to the cooling table and through the multiple saw to the scales for weighing.

When rolling large-diameter light-wall tubing, the shell is passed through the 8-stand continuous rolling mill but the Assel mill is by-passed. The tube is then reheated and passes through the 12-stand sizing sinking mill and through the rotary sizer. The latter is conventional, with the rolls set at an inclined axis. From this mill the sized tube moves to the cooling table, through the multiple cold saw and on to the scales.

The cooling table is 160 ft long and of a rotating screw-roller type. As the tubes are carried across, they oscillate back and forth across the rollers approximately 6 ft.

Electric Welded Tube Facilities

The new electric-weld tube mills produce tubes from ½ in. to 5 in. o.d. There are three, a 2-in., a 3-in.

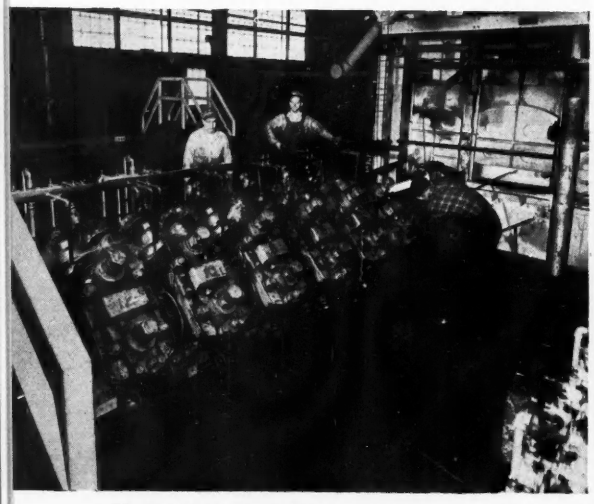


Fig. 1. **A heated seamless tube leaving the reheating furnace and entering the 12-stand stretch reducing mill.**

Fig. 2. **Seamless tubes are delivered by this rotating screw roller-type cooling table.**

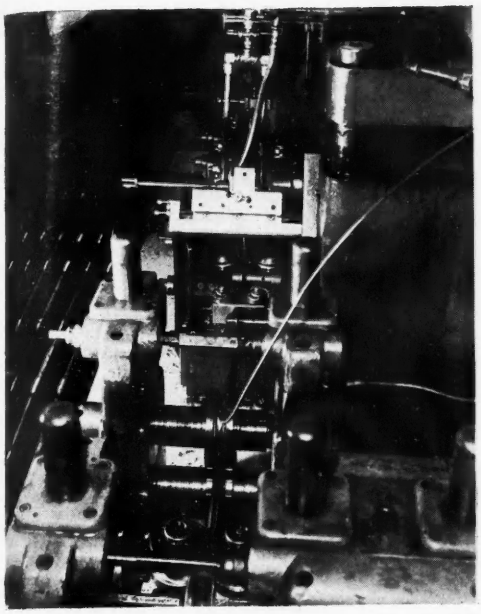


Fig. 3. **Forming and welding steel strip on an electric weld tube mill. Material for this mill is provided from wide band coils slitted to strip of the proper size.**

and a 5-in., each consisting of a forming section, a welding section with a rotary transformer to supply the welding heat, a sizing section for sizing and rounding the tube to specified tolerances, and a rotary-head travelling cut-off.

Material for the electric-weld mills is provided from wide-band coils slitted to strip of proper size. Storage space is provided for stocking approximately 3,000 tons of 36-in. wide coils of about 14,000 lb each. This material may be either hot-finished, pickled and oiled or cold-rolled rimmed or killed steel, according to trade requirements. Additional space is provided for stocking single-width strip which has been rolled as required for the tube welders.

A complete slitting line was installed to handle all strip for the three welders. It is a combination drive and pull-through type slitter capable of preparing material up to 8 BWG (0·165 in.) by 36 in. wide. Handling facilities consist of a coil-loading ramp, an elevating-type charging buggy, a pay-off reel, recoiler, unloading buggy, banding stalls and scrap winder. Proper strip tension between the slitter and the recoiler is automatically maintained by electric controls.

To permit continuous operation of the 2-in. and 3-in. mills, looping and splicing equipment is provided. This equipment includes two splicers, each provided with a hydraulically operated up-cut shear with a clamping arrangement which automatically double shears the strip ends and clamps the squared ends into position for gas welding. The loopers accumulate 300 feet of metal which is paid out to the welders while the strip ends are clamped and welded. Coils charged to the 5-in. mill are re-threaded without end-welding.

Tubes from the electric-weld mills are transferred to the finish floor where rotary straighteners bring them to commercial tolerances. Following this operation they are cut to specified lengths on rotary-head cut-off machines. After passing through a battery of profilers, which end-face and chamfer the o.d. and i.d., the tubes are inspected and packed for shipping.

Fig. 4. **Overall view of the doughnut-type rotary hearth billet heating furnace in the No. 2 seamless mill. The streak of light in the lower right was caused by a heated billet being transferred to the roller conveyor leading to the piercing mill. The discharging machine is in the foreground, while the charging machine is at the left.**

Stainless Tube Facilities

Because of the exacting performance required of the finished product, an extensive installation for handling and processing stainless tubular products was installed, equipped with facilities of the most modern design. For proper conditioning of the seamless hot-rolled tube prior to cold working, a unit of three abrasive wet-grinding machines is employed to remove surface defects. For further refining the surface, a battery of polishing machines using abrasive cloth belts of various grits is employed.

Numerous portable devices are available for the conditioning of small sections of the internal or external surfaces of the hot-rolled hollow billets. Boring equipment is provided for a thorough conditioning of the entire internal surface. A separate pickling unit is provided for " in process " material.

Three types of annealing equipment are used to process the wide range of sizes and grades of tubing manufactured. A gas-fired, three-unit, doughnut-type continuous furnace anneals tubing within the range of 3 to 8⅝ in. o.d. This furnace has a rated capacity of 1,500 to 3,000 lb/hr, depending on size and wall thickness of the tube. Product below 3 in. o.d. is annealed in a continuous furnace heated by gas-fired radiant tubes. This furnace, 30 in. wide and 15 ft long, is equipped with water-cooled silicon carbide rolls. It has a rated capacity of 1,000 lb/hr. For small light tubing from ¼ in. to 3 in. o.d. an electric induction annealing furnace is employed. It has a rated capacity of 500 lb/hr.

Each of these furnaces can develop temperatures up to 2,150 °F. Sighted on the tube are rayotubes which record and control the tube temperature as it passes from the heating chamber to the water quench at the outlet. Each furnace is equipped with variable-speed conveyors to ensure proper treatment of any size processed.

Stainless tubing 3 in. o.d. and under is reduced in another department which is equipped with two 3½-in. tube reducers, three 2½-in. tube reducers and five 1½-in. tube reducers. Cold-drawing equipment in the stainless department consists of two 50,000-lb and one

150,000-lb drawbenches. One of the former is equipped with a reeling device to permit the drawing of stainless products over a bar. To cover the range of point sizes required in the cold-drawing operation there is one ¾-in. and one 2-in. rotary and one 800 lb hammer.

A complete complement of finishing equipment is available. This includes a 12-roll straightening machine with a capacity up to 2 o.d., a gag press straightener for 2-in. to 4½-in. tubing, one two-roll straightener with a capacity up to ¾ in. o.d., and one five-roll straightener with a capacity up to 4½ in. o.d. There are also two units of two cut-off machines each, having a capacity of 2 o.d. and 6 in. o.d. respectively.

Testing equipment consists of a coupon press with plugs, pins and gauges to perform the manipulations required of each specification. One hydrostatic tester for tubing up to 4½ in. o.d. is provided for pressure testing. This equipment can exert pressures up to 3,000 psi. Tubing above 4½ in. o.d. is sent to an adjoining unit where the straightening, cutting and hydrostatic testing is performed.

Final pickling, or " passivating," is performed in a unit of two pickling tanks and a water rinse. This unit is equipped with an individual crane operated from a floor position at the extreme end of the pickling tanks. The crane has two hooks, each individually controlled. This arrangement permits lifts of tubing to be elevated at various angles, facilitating complete drainage. After a final rinse, the tubing is blown out with live steam and air. There are four internal belt-polishers and additional external polishing equipment to produce surfaces in the grit requirements of the customer.

No. 2 Seamless Mill and Facilities

Originally built in 1930 to manufacture pipe and casing in lengths up to 48 ft, the mill was shortened to 35 ft during World War II to permit installation of additional machinery and reheating furnaces for alloy speciality goods. Under the post-war programme the mill was again changed to manufacture alloy speciality goods up to 48 ft long in sizes ranging from 3½ to 9 in. o.d. This alteration necessitated the removal of reheating furnaces and relocation and redesign of other pieces of equipment.

Among the major items of new equipment are a 60-ft doughnut-type rotary furnace of 50 tons per hour capacity, an automatic outlet-guide section trough for the No. 1 piercing mill, a reheating furnace ahead of the plug mill and a 13-chamber in-line reheating furnace ahead of the continuous sizing mill.

The rotary furnace is designed to incorporate five individual walled zones, each with its own separate furnace controls and equipped to burn oil or gas, or oil and gas in combination. A machine automatically feeds cold rounds as required onto a conveyor. The conveyor, in turn, is automatically activated from the discharge end of the furnace by the manually operated discharging machine.

Finishing Floors

Two finishing floors handle the full range of seamless products manufactured on the No. 2 and No. 3 mills. No. 1 floor is located near No. 3 seamless mill and processes both hot-rolled and cold-drawing tubing from $\frac{3}{16}$ in. to 3½ in. o.d. No. 2 floor is located near No. 2 seamless mill and can handle tubing of 3½ to 9 in. o.d. Both floors are equipped with straightening

(*Concluded on page* 328)

FRANCE

Correlation of the Deep-Drawing Qualities of a Material and its Tensile Test Results

By C. ARBEL. (From *Revue de Métallurgie*, Vol. 47, No. 5, May, 1950, pp. 388-394, 14 illustrations.)

The deep-drawing qualities of a metal are here characterised by the largest blank diameter that can be drawn into a cylindrical cup without failure on a given set of tools. This figure is correlated to the modulus of plasticity deduced from the true-stress/true-strain (area reduction) diagram of the simple tension test by logarithmic plotting. Certain conclusions can be drawn.

THE most important property for the deep-drawing of a metal, its " deformability," is determined by the manner in which the metal behaves after an appreciable deformation has taken place. This information is given in a simple form by the true-stress/true-strain diagram of the tensile test. The " true stress " $f_t = F/A$ is here understood to be the ratio of the instantaneous load to the instantaneous minimum cross-section of the test piece, while the " true strain " $e_t = \log_e (A_o/A)$ is the logarithm of the ratio of initial to minimum cross-section at any stage of the test. For an evaluation of the experimental curves represented by such diagrams, the formula

$$f_t = K e_t^n \quad .. \quad .. \quad (1)$$

has been suggested, K being a scale factor in psi, and n the " modulus of plasticity," characterising the shape of the curve. Fig. 1 shows two materials of equal ultimate strength but different moduli n. Evidently, a given deformation of Material A will require more work than the same deformation of Material B. Materials of equal modulus n but different factors K (Fig. 2), however, deform similarly, even though the forces required may differ greatly. If a sound circular sheet of a ductile metal is drawn into a cylindrical cup, failure always takes place as a simple tensile fracture near the bottom of the cylindrical part, and the punch force then corresponds fairly well to the theoretical ultimate force which the material is able to sustain[1]. Correct evaluation of the tensile test should thus supply us with a valid criterion of the deep-drawing qualities of a metal.

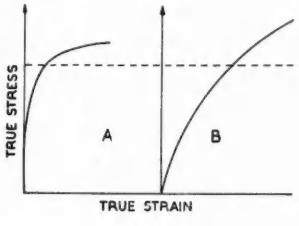


Fig. 1

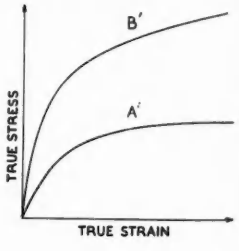


Fig. 2

The metals tested were

(a) 65/35 brass, received hard, annealed 40 minutes at 540 C, Rockwell-B = 63·5 ;
(b) 18/8 stainless steel, annealed condition ;
(c) commercially pure copper, annealed, Rockwell-B = 44 ;
(d) 3 S-O aluminium alloy with 1 to 2 per cent Mn, annealed ;
(e) 52 S-O aluminium alloy with 2·5 per cent Mg, 0·25 per cent Cr, annealed ;
(f) 65/35 brass, hard as received, Rockwell-B = 99·5.

The last material is unsuitable for deep-drawing. It showed a strong rolling orientation and was only tested for purposes of comparison. Sheets of $\frac{1}{8}$ in. thickness were chosen because they do not fold when drawn without pressure flange, and also because their minimum cross-section can be measured during the tensile test without any appreciable relative error.

Deep-drawing tests.

Punch and die block (Fig. 3) were fitted in an Olsen testing machine. No pressure flange was used and ample clearance was provided between punch, drawn cup, and die, so that friction was minimised. The blank was turned to size on a lathe and greased. The force exerted on the punch during tests not leading to fracture was measured as a function of the punch displacement (Fig. 3). The maximum force was noted and

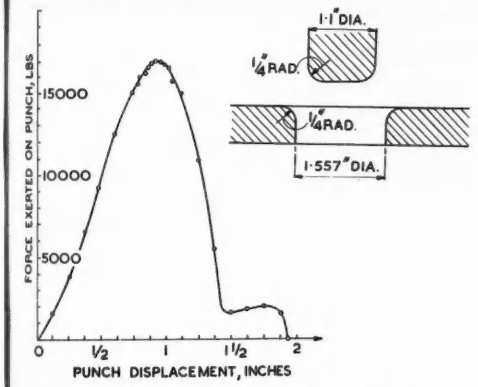


Fig. 3. **Test punch and die block, and deep-drawing diagram for annealed brass. Blank diameter 2·6 inches.**

corrected for variations of the sheet thickness[2] which was measured at four points of the blank and averaged. (The force changes proportionally with the change of blank thickness). If the corrected maximum force is represented as a function of the original blank diameter, an approximately straight line of increasing force with increasing diameter is obtained. This line is extrapolated to a value of the force which corresponds to the theoretical ultimate force sustainable by the respective material. The blank diameter corresponding to this extrapolated point is the maximum diameter that can be drawn without tensile fracture under test conditions as described. The ratio of maximum blank diameter to punch diameter finally is used as a criterion of the deep-drawing qualities of the tested material (see Fig. 9).

Tensile Tests.

The tensile test specimens (Fig. 4) for the Olsen machine had two very shallow, milled grooves, so that the striction effect could be localised. Specimens were taken parallel, at 45 degrees, and normal, to the direction of rolling. The minimum cross-section was measured by micrometer, and the minimum thickness plotted as a function of the minimum width. The majority of measurements then showed a straight-line graph for the entire test of each specimen. Only a few measurements were corrected to coincide with this straight line. It became evident that the slope of the line, i.e., the thickness/width ratio, had the expected value of about 0·25 (see Fig. 4) only for wholly isotropic materials

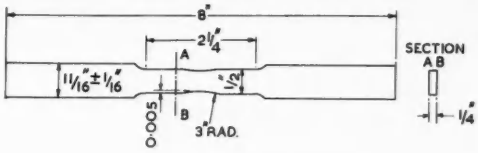


Fig. 4

(brass, copper, stainless steel), but that its value changed with the orientation of the test specimen if the material was partly anisotropic. The 52 S-O aluminium alloy, for example, tends to retain the rolling anisotropy and showed the following values :

Angle of specimen axis to direction of rolling	0°	45°	90°
Slope of line representing thickness as function of width during test	0·50	0·30	0·43

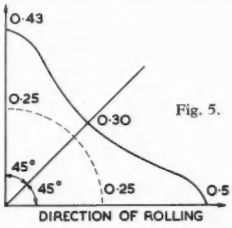


Fig. 5. **Polar diagram of anisotropy.**

Here, then, is a quantitative criterion of the anisotropy of a material. A polar diagram (Fig. 5) would give a graphic illustration of the effect that the more the curve

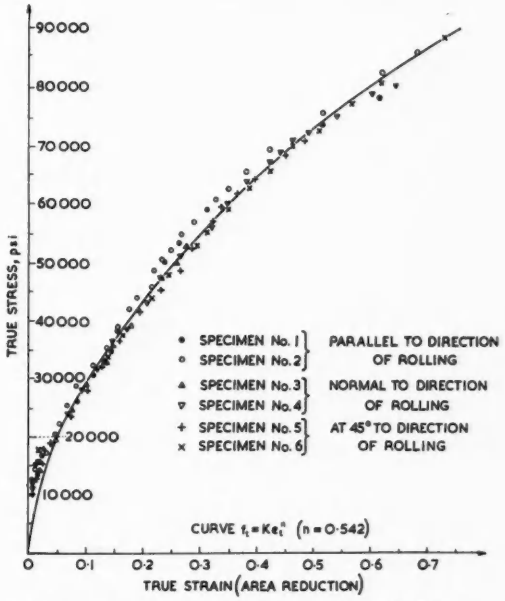


Fig. 6. **True-stress/true-strain diagram of annealed brass.**

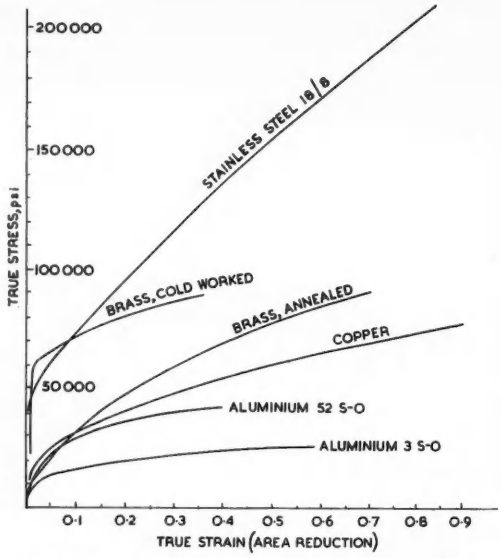


Fig. 7. **True-stress/true-strain diagrams of materials tested.**

for a specific material deviates from the circle of complete isotropy, the stronger is the anisotropy of that material.

The true-stress and true-strain values were calculated and the diagram plotted for each material. Fig. 6 shows a typical diagram, and Fig. 7 gives the average curve for each tested material. The effects of anisotropy are hardly noticeable in these diagrams. By plotting on logarithmic scales (Fig. 8), we can then determine the modulus n for a sufficient range of deformations, if the scatter values of small deformations are ignored. The scatter is more pronounced for stainless steel than other materials, probably because cold work is accompanied by precipitation of a ferritic phase. Hard brass, like other cold-worked materials, does not generally follow the formula (1), and a mean value of n has here been assumed for the small deformations which this material is able to suffer without fracture. Soft brass finally showed another anomaly : Throughout the test, the deformation occurred in small jumps. The width of one section would suddenly decrease by about 0·005 in., and the decrease spread by jumps throughout the specimen. Another similar jump would then reduce the cross-section further, and the decrease again spread along the specimen, etc. The process reminds one of similar phenomena during the appearance of Luders lines, but here the jumps continued throughout the test until fracture occurred.

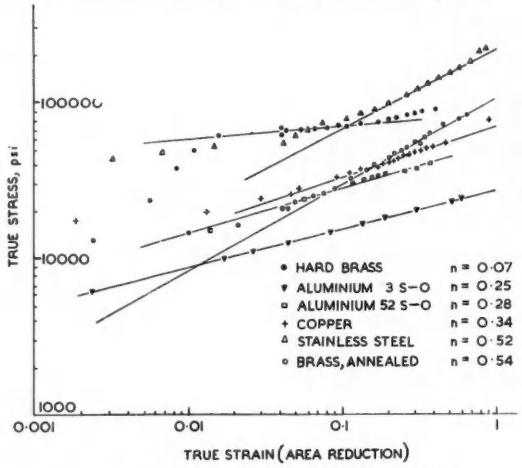


Fig. 8. **Determination of the modulus of plasticity n.**

Conclusions.

Although the small number of metals tested does not admit of making any final deductions, a provisional curve has been drawn (Fig. 9) linking the results of the tensile test, i.e., the modulus of plasticity n, to those of the deep-drawing test, i.e., to the maximum blank diameter that can be deep-drawn into a cylindrical cup without fracture, when a given set of tools is used. The slight deviations from the curve drawn may be due to (a) deviations of the material from the theoretical modulus n, (b) measuring errors, (c) friction influences. The curve of Fig. 9 shows that even if metals of a still higher modulus of plasticity n were manufactured, no noticeable further improvement in deep-drawing qualities could be expected.

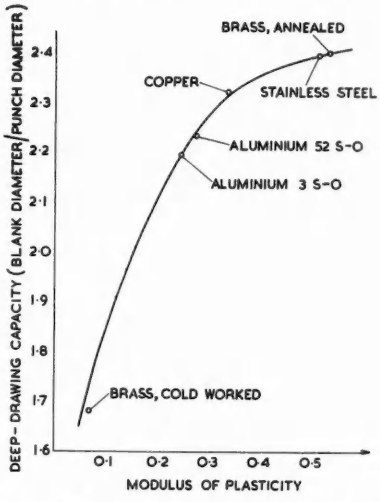


Fig. 9. **Relation between modulus of plasticity and deep-drawing properties.**

The author also suggests that the modulus of plasticity n should be used commercially as a criterion of the deformability and cold-working capacity of a material, and should supersede the present use of the elongation at fracture. The mechanical significance of this modulus can be derived as follows: We differentiate eq. (1), so that $df_t = n\,Ke_t^{n-1}\,de_t$, and divide again by eq. (1), thus obtaining

$$\frac{df_t}{f_t} = n\frac{de_t}{e_t}. \qquad \ldots \qquad \ldots \qquad (2$$

By definition, we have $e_t = \log_e (A_0/A)$ and $de_t = -dA/A$. The conventional load-deflection diagram, on the other hand, shows that when the ultimate load F_{max} is reached, a small further elongation, or reduction of area dA_m, is possible without any change of load. With $f_{tm} = F_{max}/A_m = \text{const}/A_m$ and $df_{tm} = -\text{const}\,dA_m/A_m^2$, we therefore have

$$\frac{df_{tm}}{f_{tm}} = -\frac{dA_m}{A_m} = de_{tm}, \qquad \ldots \qquad (3$$

where f_{tm} is the true stress, and A_m the minimum cross-section under the load F_{max}. Although F_{max} has no special significance for the true-stress/true-strain diagram, eq. (2) must be valid for the corresponding point of this diagram, i.e., for f_{tm} and e_{tm}. By comparison of eqs. (2) and (3), we then find

$$n = e_{tm} = \log_e (A_0/A_m), \quad .. \quad .. \quad (4)$$

i.e., the modulus of plasticity n is the true strain corresponding to the ultimate tensile loading. Up to the ultimate load, i.e., before local restriction sets in, the true strain (expressed as area reduction) is an unique function of the conventional elongation, so that the *elongation at ultimate load* is also a measure of the modulus n, and hence a criterion of the deformability of the material. However, the determination of n by the method of Figs. 6 and 8 is much more accurate than the measurement of the elongation at ultimate load.

REFERENCES

(1) E. L. BARTHOLOMEW, JR., Stress-strain measurements in the drawing of cylindrical cups. *Trans. A.S.M.*, 1943, p. 582.

(2) S. FUKUI, Researches on deep-drawing, *Inst. Phys. and Chem. Researches, Tokyo*, 134, Oct., 1938, 1.422.

U. S. A.

The Mechanical Rectifier

By O. JENSEN. (From *Iron and Steel Engineer*, Vol. 27, No. 4, April, 1950, pp. 69-75, 9 illustrations.)

A new type of conversion equipment incorporating mechanical rectifiers originally developed in Germany is now in production in the U.S.A. The rectifier equipment is available in various sizes* (50, 200, 625, 1250, 2500, 5000 and 10,000 *amperes*) *in the d.c. voltage range from* 50 *to* 400 *volts.*

THE mechanical rectifier consists of a set of commutating reactors with pre-excitation control, contact mechanisms with corresponding control circuits, protective equipment for the a.c. and d.c. circuits, and interlock devices preventing faulty operation by the operating personnel.

The working principle can be followed by considering the half-wave rectifier circuit of Fig. 1 in conjunction with the curves of Fig. 2. The contacts $K_{a,b,c}$, driven by a synchronous motor M, are spaced 120 electrical degrees apart. When contact K_a is closed, phase a delivers the load current I_a. Contact K_b closes at point A of the cycle. A short-circuit current I_b (limited only by the corresponding circuit impedance) then flows from transformer phase b to a, and is superimposed on current I_a which decays in a cosine pattern. At point B, I_a reaches zero and contact K_a can be opened without any arc. The short-circuit is then removed and the load is carried by phase b until commutation occurs at C, when the process is repeated.

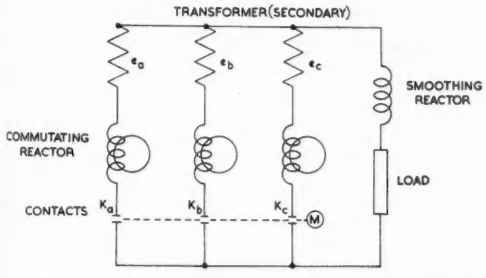


Fig. 1. **Basic diagram of half-wave mechanical rectifier.**

In order to obtain a short interval of practically zero current at the end of the commutation period, and to permit opening of the contact without an arc, three commutating reactors with cores of a special magnetic alloy are inserted between the transformer terminals and the contacts. The cores have a nearly rectangular magnetisation curve, and the slant of this curve is compensated for by special control circuits, so that a flat step is obtained, and this enables the rectifier to operate under variable load conditions within its guaranteed minimum and maximum current rating.

No change of flux takes place in the core while I_a decays from load value to zero, until a small negative value of current has been reached. This negative current is supplied by a control winding so that a step current of true zero value is obtained in the main winding during commutation. The reactors then become highly inductive and no further current change can occur until the flux has changed from positive to negative saturation. The contact K_a can be opened is any time during this step. The length of the step at equal to the period of flux reversal, and this depends

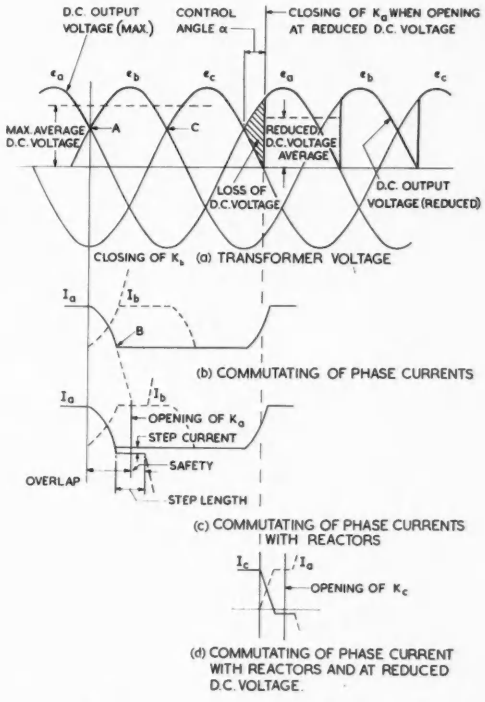


Fig. 2. **Relationship between rectifier voltages and currents.**

* See *The Engineers' Digest*, December, 1941, pp. 465-467.

on the voltage across the main winding during the step, the number of turns of the main winding, and the core cross-section.

As in a mercury rectifier, control of the d.c. output voltage is possible in the downward direction only, by altering the point at which commutation begins. The d.c. voltage decreases with increasing delay, and automatic controls are available for constant current, voltage, or wattage, according to the customer's requirements.

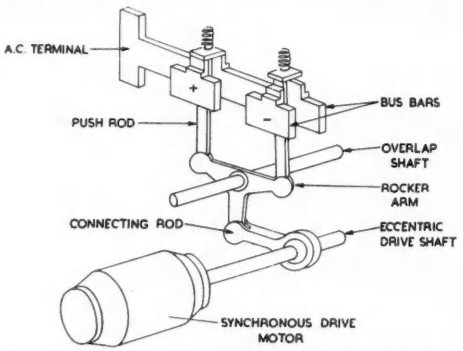


Fig. 3. **Schematic diagram of contact-operating mechanism.**

A schematic diagram of the reciprocating contact mechanism for one phase is shown in Fig. 3. Flat non-sliding silver contacts are used. An eccentric, rotated by the synchronous motor, oscillates through a connecting rod, a rocker arm giving a sine-type motion to each of the contact push-rods on either side of the rocker-arm pivot. With this arrangement the two contacts are 180 electrical degrees apart, and give a 6-phase rectification for a 3-phase transformer. Reciprocating contacts, as compared with rotating contacts, have the following advantages: (1) contact time adjustment is easier; (2) frictional losses are eliminated; (3) the ohmic drop through the contacts is considerably smaller, and (4) much smaller contact areas can be used ($1\frac{1}{8}$ in. diameter for a 500-A machine).

The mechanical rectifier has a high efficiency in its voltage range, as shown in the following table:—

Volts	100	200	400	600	800
	Efficiency, per cent				
Mechanical rectifier ..	96	96·8	97·2	97·5	97·5
Mercury arc rectifier ..	87·5	90	93	95	95·5
Rotary converter ..	90	92·2	93	93·5	93·5
Motor generator	87·5	88·5	90·5	91	91

Small space requirements, low installation and maintenance costs, instantaneous availability for operation without a warming-up period are further advantages of this rectifier. Replacement of the contacts, normally required after about 18 months, can be made in 10 minutes for a 5000-A machine, and the bearings of the mechanism have a life exceeding 50,000 hours.

The limitations are a relatively low power factor of 86-90 per cent, and the tendency to backfire under excessive overload or after an interruption or loss of 60 per cent of the a.c. voltage. Protection of the contact mechanism is ensured in both cases by a limiting device operating whenever the a.c. input does not balance the d.c. output. This device short-circuits in 1/1000th of a second the a.c. and d.c. sides of the mechanism. The d.c. breaker then trips owing to the reverse current and the a.c. breaker trips under the overload. Damage due to backfiring affects at most one or two contacts, which should be replaced at the earliest opportunity By leaving the iron-core commutating reactors in the circuit, a zero-current step is produced which halves the short-circuit current, and this materially reduces the short-circuit stresses on the a.c. side.

To date, two fairly large 12-phase installations have been set up, one operated at 25 cycles, and the other at 60 cycles.

A schematic wiring diagram of the 25-cps installation is shown in Fig. 4. The installation consists of two units, rated at 3500 A, 280 V d.c. each, with a mains supply of 11,000 V. To obtain 12-phase operation, one of the two transformers is star-connected and the other delta-connected on the primary side, the secondary being delta-connected in both transformers. Each transformer is protected with an oil circuit breaker equipped with C.O. relays, with an overload device set at 150 per cent of the rated current. Four current transformers are connected between the commutating reactors and the secondary transformer terminals. Three are for the operation of the short-circuit device, and the fourth is for the constant current regulator. This regulator has been provided with a magnetic amplifier instead of a contact-making relay, and the motor stator is shifted by a hydraulic servo-mechanism. The three commutating reactors of each unit are connected between the secondary transformer terminals and the contact mechanism.

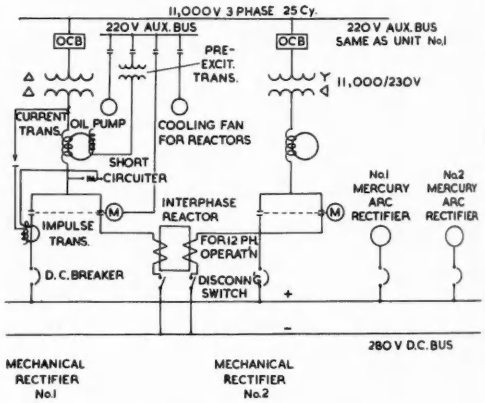


Fig. 4. **Schematic wiring diagram of 25-cps installation.**

The reactor pre-excitation is automatically adjusted in a circuit consisting of two transformers, fed from the main transformer secondary and from the auxiliary circuit, respectively. The auxiliary circuit is fed from a 220-V 3-phase source. Inserted in the positive lead of each contact mechanism are an impulse transformer for short-circuiter control and a high-speed breaker which protects the d.c. side and connects the unit to the load. The negative lead is connected to an interphase reactor and a disconnecting switch. The equipment also includes the synchronous drive motor with low rotor inertia, a motor driving the coolant circulating pump, the oil pump and the coolant fan, a fan motor for cooling the commutating reactors, and a contactor for the pre-excitation circuit. Compressed air is used for re-setting the short-circuiter.

BIBLIOGRAPHY

F. KOPPELMAN: (1) The contact converter. "Elektrotechn. Zeits.," Jan., 1941. (2) Contact converters for heavy-current installations. "Techn. Beschreibung AJE," No. 98. (3) The electro-technical principles of the contact converter. "Elektrotechnik u. Maschinenbau," Vol. 59, No. 23/24, 1941; Vol. 60, No. 17/18, 1942; Vol. 60, No. 35/36, 1942. (4) Method for measurements on annular cores. "Archiv für Elektrotechnik," Vol. 38, No. 3/4, 1944.

Aerosol Indicator for Rapid Testing of the Dust Content of Air

By G. LJUNGGREN and T. WILNER. (From *Teknisk Tidskrift*, Vol. 80, No. 23, June 10, 1950, pp. 551-552, 2 illustrations.)

The apparatus described in this article allows of directly determining the dust content of air. Operating in the same way as an ultramicroscope, observation of dust particles ranging down to one half micron is possible

THE air of premises in which work is being carried out usually contains dust. This may consist of solid particles produced as a result of handling, crushing, or grinding, or caused by sudden impact, detonation or explosion of organic or inorganic materials, such as rock, ores, metals and coal. The air may also contain impurities produced by the condensation of vapour from molten metal or fumes due to chemical reactions. Finally, the air may contain liquid droplets formed by the condensation or vaporisation of liquids, for instance, during sprinkling or emulsifying operations. Some types of dust are dangerous and can give rise to industrial diseases.

The following table gives the times taken by various dust particles with a specific weight of 2·5 to fall through a distance of one metre in still air, assuming the particles to be of spherical shape and using Stokes' law :—

Diameter	100	10	5	1	0·5	0·2 μ
Falling time	1·9 sec	2·2 min	9 min	3 hrs	11 hrs	46 hrs

(1μ = 1/1000 millimetre = 0·000 039 4 inch).

This table shows that particles with a diameter exceeding 10μ fall fairly rapidly to the ground and, therefore, do not remain in the air for any appreciable length of time. They can be removed by filtering, and therefore particles of this size seldom get into the lungs. Particles with a diameter of 1μ take 3 hours to fall through 1 metre. This means that they are able to float in the air and follow its motion. Particles between 1μ and a few tenths of a μ can thus penetrate into the lungs and remain there. Particles of still smaller size are relatively less important in view of the very small amount of matter which they represent.

The various types of dust can be divided into two main groups :—(1) poisonous substances, such as cadmium or lead, and (2) substances which are not poisonous in themselves, but which, nevertheless, in the form of dust, may cause appreciable damage. In this latter group are included substances such as silica, asbestos and organic impurities. The maximum number of particles of this type which may occur in a cubic centimetre of air without producing effects injurious to health is given in the following table :—

	1. Substances including more than 50% silica and asbestos	2. Substances including between 5% and 50% silica	3. " Ordinary dust " with mainly organic impurities
Max. allowable concentration, particles/cm^3	200	800	2000

Particles smaller than 10μ are not discernible by the naked eye. It is therefore possible, in some cases, that dust which is easily visible may not be dangerous, whereas premises which appear to be free from dust may, in fact, be extremely unhealthy to work in. Many dust filters do not stop dust particles of the order of 1μ or less. As the dangerous particles are not visible, it is necessary to have a simple method for detecting the presence of fine particles. The dust should be eliminated at the place where it is being formed. This can be achieved by means of suction systems arranged at the appropriate positions, and it is necessary to check the effectiveness of these systems.

DUST DETERMINATION

There are various methods for determining the dust occurring in air. The number of particles and their size and weight can be determined. The laboratory method consists in enclosing a number of particles in a glass vessel, counting them, and measuring their size with a microscope. This method is tedious, particularly when large numbers of samples have to be taken.

It was therefore found necessary to develop a simple method for determining the dust content of air directly, in the works' premises ; the method should also make it possible to follow the dust variations and thus check on the ventilation.

The " Aerosol Indicator " was, therefore, developed on the basis of designs prepared by the authors. With this apparatus it is possible to observe particles of sizes ranging down to $0{\cdot}5\mu$, in suspension in the air. The Aerosol Indicator operates in the same way as an ultramicroscope. The air being examined is drawn into the apparatus by means of an electrically operated fan. The particles in the air are illuminated from the side, with a very strong light intensity, against a dark background. With this dark-field illumination, particles are visible which are too small to be noticed with an ordinary microscope. The apparatus is very easy to operate. It includes a battery in a portable case and tests can be carried out rapidly at any place requiring investigation.

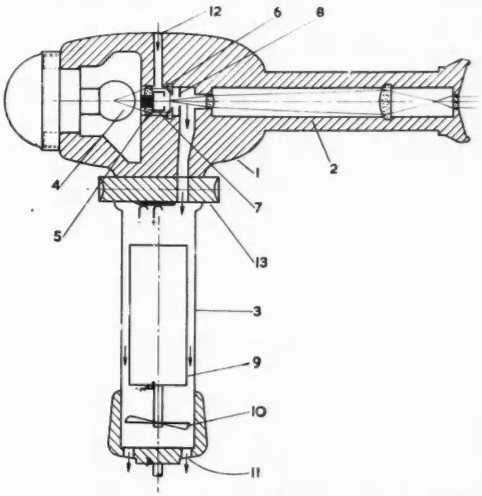


Fig. 1. **Schematic sectional view of the Aerosol Indicator.**

Fig. 1 gives a schematic sectional view through the Aerosol Indicator. The body (1) of the apparatus contains the light unit and the observation chamber, and into it is screwed the microscope tube (2), which has a

linear magnification of ×35. The handle (3) contains an electric motor (9) driving the fan (10). The illumination is provided by an electric bulb (4) fitted into an easily unscrewable cap. The light rays pass through the condenser lens (5), reach the annular concave mirror (6) and then converge at the focal point of the mirror, giving a high light intensity at this position. The concentrated beam has here the shape of a layer of non-uniform thickness. In the microscope it is then possible to see such objects as are in the illuminated area of the microscope field. The cup-shaped mask (7), which has its bottom surface well in the shaded area, acts in conjunction with the annular mask (8) to prevent any stray light from entering the microscope tube.

The air sample is aspirated into the apparatus through the opening (12), passes the observation space, and then goes through the hollow knob (13), which serves as a control valve, and down through the handle (3), until it is finally expelled by the fan through the outlet aperture (11). Knob (13) used for controlling the flow has three different settings. When the knob is pushed into the upper position, the air valve is closed and there is no air flow. With the knob in the middle position, the valve is open and air can flow through. By pressing the knob downwards to the left, the air chamber is closed, the illumination switched on and the fan stopped.

(*Continued on page* 320)

ITALY

Calculations of the Direct Illumination Produced by Tubular Lamps

By G. PAROLINI and M. CALZINI. (From *l'Elettrotecnica*, Vol. 37, No. 4, April, 1950, pp. 182-187, 8 illustrations.

In this article the direct illumination produced by tubular lamps or strip lights on planes parallel or perpendicular to the lamp axis is calculated, and diagrams are given for a graphical determination of the illumination.

THE illumination will be calculated on the basis of the following assumptions: (1) the luminous flux density is constant over the entire length of the source; (2) the light intensity emitted in various directions from an element of area of the tubular or strip light follows the cosine relationship of Lambert's law ; (3) the transverse dimensions of the illuminating body are small relatively to the distance between the body itself and the surface for which the illumination is to be determined.

If Φ = total flux, and S = area of radiating surface, then the flux density $l = \Phi/S$ and the corresponding brightness is given by

$$\sigma = l/\pi = \Phi/(\pi S) \quad .. \quad .. \quad (1)$$

DETERMINATION OF FLUX

The illumination received by a small area dA of a plane arranged in any direction relatively to the lamp axis may be regarded as the sum of the elementary illuminations contributed by each infinitesimal element dx of the tube length.

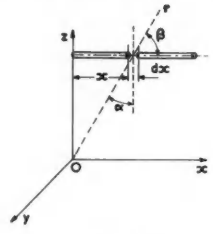


Fig. 1

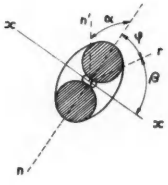


Fig. 2

Considering Fig. 1, let the tubular lamp be situated parallel to the x-axis at a height Z from the xy-plane. If Φ is the total flux emitted by the entire tube of length X, then the flux per unit length of the tube is

$$\Phi_1 = \Phi/X.$$

If I_n = light intensity in the direction normal to the tube axis, and I = intensity of a ray at an angle φ from the normal to the tube, then

$$I = I_n \cos\varphi = I_n \sin\beta$$

where $\beta = (\pi/2) - \varphi$. The photometric solid is a torus with an inner diameter equal to zero. The light intensity thus depends on the angle β in a plane parallel to the xy-plane, but does not vary with the angle α (see Fig. 2) formed by the ray with the z-axis. The flux of the tubular element is, therefore, given by

$$\Delta\Phi_1 = \int_0^{\pi} d\beta \int_0^{2\pi} d\alpha\, I \sin\beta = 2\pi \int_0^{\pi} d\beta\, I \sin\beta$$

or $$\Delta\Phi_1 = 2\pi I_n \int_0^{\pi} d\beta \sin^2\beta = \pi^2 I_n$$

so that $$I_n = \Delta\Phi_1/\pi^2 \quad .. \quad .. \quad (2)$$

Equation (2) shows that the flux emanating from a tubular lamp can be determined by measuring the luminous intensity in a direction normal to an element of the tube. This measurement is much more easy to effect than a complete determination of the flux.

ILLUMINATION OF AN AREA IN A PARALLEL PLANE

(a) *Tubular lamp.* The co-ordinate axes will be chosen so that the element of area dA, in the xy-plane, for which the illumination is to be calculated, is situated on the y-axis, and has the co-ordinates $(0, Y, 0)$ as shown in Fig. 3.

The illumination of dA due to an element of the tube dx (with the co-ordinates $(x, 0, Z)$ will now be calculated. Let φ = angle between the plane normal to dx in the xy-plane and the line of length R connecting dx to dA. The light intensity in this direction is given by

$$I = I_n \cos\varphi = \Delta\Phi_1 \cos\varphi/\pi^2 \quad .. \quad (3)$$

and as $\cos\varphi = \rho/R$ where $R = \sqrt{x^2 + \rho^2}$ and $\rho = \sqrt{Y^2 + Z^2}$ = projection of R on the yz-plane, Z being the distance of the tube from the xy-plane, therefore

$$I = \Delta\Phi_1 \rho/(\pi^2 R).$$

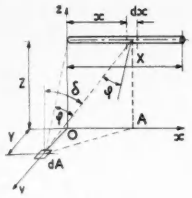


Fig. 3

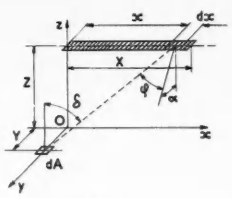


Fig. 4

The contribution to the illumination of dA is then

$$\Delta E = I\cos\delta/R^2 \quad .. \quad .. \quad .. \quad (4)$$

where R = distance from dA to dx, and δ = angle between the normal of dA and the line connecting dA to dx. Therefore,

$$\cos\delta = Z/R$$

and $$dE = d\Phi_1\, Z\rho/(\pi R)^2.$$

In the above equation, $\Delta\Phi_1$, the finite flux emitted by a small area of the tube regarded as a point source, has been replaced by $d\Phi_1$. This is because the usual definition of light intensity is not applicable to extensive sources, since for these the flux tends towards zero as the radiating surface tends towards zero.

As the flux emitted by an element dx is:

$$d\Phi_1 = \Phi_1\, dx$$

we have $$dE = \Phi_1\, Z\rho\, dx/(\pi R)^2.$$

In this equation, the illumination is expressed by means of a few known constants (co-ordinates of dA and of the tube, flux per unit length of tube, etc.) and by a single variable, the co-ordinate x of the radiating element dx. The illumination produced by the entire tube of length X is, therefore,

$$E = \frac{\Phi_1\, Z\,\rho}{\pi^2}\int_0^X \frac{dx}{(x^2+\rho^2)^2}$$

or $$E = \frac{\Phi_1\,\rho}{2\pi^2\, Z}\left[\frac{X}{X^2+\rho^2} + \frac{1}{\rho^2}\tan^{-1}(X/\rho)\right] \quad (5)$$

This is the most general expression for the illumination of any small area dA in a plane parallel to the tube axis. If the tube extends into the space in which x assumes negative values, the calculation is repeated and the result is added to that obtained for the space in which x is positive. Moreover, if the luminous tube begins at a point X' from the origin O, and ends at X, the value of E' is obtained by substituting X' for X in eq. (5), and the resultant illumination is

$$E_{res} = E(X) - E'(X')$$

The illumination can also be expressed in terms of the brightness σ instead of the flux, by using eq. (1). If d = constant diameter of the tube, the area of the radiating surface will also be a function of x:

$$S(x) = x\pi d$$

hence $$\sigma = \Phi/(x\pi^2\, d)$$

For a unit length of tube, $x = 1$ and $\Phi = \Phi_1$, therefore,

$$\sigma = \Phi_1/(\pi^2 d) \quad \text{or} \quad \sigma\, d = \Phi_1/\pi^2$$

and substituting this in eq. (5) gives

$$E = \frac{\rho\sigma d}{2Z}\left[\frac{X}{X^2+\rho^2} + \frac{1}{\rho^2}\tan^{-1}(X/\rho)\right] \quad .. \quad (6)$$

(b) *Luminous strip.* If the radiating surface can be regarded as a luminous strip of small width, situated in a plane parallel to the xy-plane (see Fig. 4) which contains the small area dA for which the illumination is to be determined, the calculation will have to be modified as follows. The strip is regarded as a luminous line consisting of elements dx with a finite but very small width $\Delta y = d$. Each strip element then becomes a point source radiating according to the cosine law. If Φ_1 = the flux emitted by the element dx, the light intensity in the normal direction is given by

$$I_n = \Delta\Phi_1/\pi \quad .. \quad .. \quad (7)$$

which thus replaces eq. (2), the latter having been used in the case of a tube. With eq. (7), and Lambert's law, the expression for the light intensity of the ray emanating from the element in any direction determined by the angle δ formed by the ray with the normal of the element is (see Fig. 4):

$$I = I_n\cos\delta = \Delta\Phi_1\cos\delta/\pi$$

where $\cos\delta = Z/R$ and $R^2 = x^2 + \rho^2$ as previously.

The contribution of the strip element dx to the illumination of dA is

$$dE = I\cos\delta/R^2$$

and substituting in this equation the values for I and R, and replacing as previously $\Delta\Phi_1$ by $d\Phi_1 = \Phi_1\, dx$, we have

$$dE = d\Phi_1\, Z^2/(\pi R^4) = \Phi_1\, Z^2\, dx/(\pi R^4),$$

so that the total illumination of dA due to the strip extending from $x = 0$ to $x = X$ is

$$E = \frac{\Phi_1\, Z^2}{\pi}\int_0^X \frac{dx}{(x^2+Y^2+Z^2)^2}$$

or $$E = \frac{\Phi_1}{2\pi}\left[\frac{X}{R^2} + \frac{1}{\rho}\tan^{-1}(X/\rho)\right] \quad (8)$$

This equation is similar to eq. (5). The illumination can also be expressed in terms of brightness instead of flux, by using eq. (1). Since $S(x) = xd$ and $\delta = \Phi/(x\pi d)$, the brightness is given by $\sigma = \Phi_1/(\pi d)$ so that

$$\sigma d = \Phi_1/\pi$$

and eq. (8) becomes

$$E = \frac{\sigma\, d}{2}\left[\frac{X}{R^2} + \frac{1}{\rho}\tan^{-1}(X/\rho)\right] \quad .. \quad (9)$$

To determine the flux per unit length Φ_1 it will be sufficient to apply eqs. (5) or (6) and measure the mean value of the illumination on a diffusing glass surface or in a luminous cavity. Knowing, or assuming a value for, the transparency coefficient of glass or the diffusion coefficient of the inner surface of the cavity, the mean value of the illumination can be calculated, and from this, using Lambert's law, the values of Φ_1 and σ are obtained.

ILLUMINATION OF AN AREA IN A PERPENDICULAR PLANE

In this case, the tube will be assumed to be orientated along the x-axis, with the y-axis pointing downwards, as shown in Fig. 5. The small area dA, for which the illumination is to be calculated, is situated in the yz-plane.

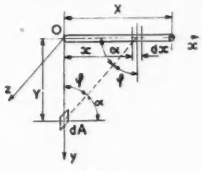


Fig. 5

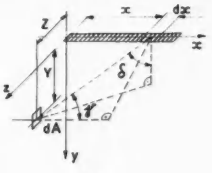


Fig. 6

The lines of equal light intensity on the yz-plane will obviously be circles with their centres at the origin. For simplicity, the small area dA will be assumed to be situated on the y-axis, with the co-ordinates $(0, Y, 0)$.

The calculation is similar to that carried out for the previous cases.

(a) *Tubular lamp.* If Φ_1 is the radiated flux, the light intensity in the direction of the line R connecting dx (tube element with the co-ordinates $(x, 0, 0)$) to dA will be

$$I = I_n \cos\varphi = \Delta\Phi_1 \cos\varphi/\pi^2$$

and the contribution to the illumination of dA is

$$dE = d\Phi_1 \cos\varphi \cos\alpha/(\pi R)^2,$$

where α = angle between R and the normal to dA. Substituting the values for $\cos\alpha$ and $\cos\varphi$ gives

$$dE = d\Phi_1 \, xY/[\pi (x^2 + Y^2)]^2$$
$$= \Phi_1 \, Y \, xdx/[\pi (x^2 + Y^2)]^2.$$

The illumination of dA due to a length of tube extending from $x = 0$ to $x = X$ is

$$E = \frac{\Phi_1 \, Y}{\pi^2} \int_0^X \frac{x \, dx}{(x^2 + Y^2)^2}$$

or

$$E = \Phi_1 \, X^2/[2\pi^2 \, Y \rho'^2]$$

where $\rho'^2 = X^2 + Y^2$.

Using the same notation as previously, the expression for E in terms of the brightness is then

$$E = X^2 \sigma \, d/(2\rho'^2 \, Y) \quad .. \quad .. \quad (11)$$

(b) *Luminous strip.* The strip will be assumed to be situated as shown in Fig. 6, along the x-axis. Then, as

$$I_n = \Delta\Phi_1/\pi$$

the light intensity in the direction of R joining dA and dx will be

$$I = I_n \cos\delta = \Delta\Phi_1 \cos\delta/\pi$$

and the contribution to the illumination of dA is

$$dE = d\Phi_1 \cos\delta \cos\gamma/(\pi R^2)$$

where δ = angle between R and the normal to dx, and γ = angle between R and the normal to dA. Replacing $\cos\delta$ and $\cos\gamma$ by their respective values gives

$$dE = d\Phi_1 \, xY/[\pi (x^2 + \rho^2)^2]$$
$$dE = \Phi_1 \, Yxdx/[\pi (x^2 + \rho^2)^2]$$

where $\rho^2 = Y^2 + Z^2$.

The illumination produced by a strip extending from $x = 0$ to $x = X$ is, therefore,

$$E = \frac{\Phi_1 \, Y}{\pi} \int_0^X \frac{x \, dx}{(x^2 + \rho^2)^2}$$

$$= \Phi_1 X^2/[2\pi \, Y (X^2 + \rho^2)] \quad .. \quad (12)$$

or

$$E = X^2 \sigma \, d/[2Y (X^2 + \rho^2)] \quad .. \quad (13)$$

GRAPHICAL DETERMINATION OF THE ILLUMINATION

The illumination can be calculated for the various cases by means of eqs. (5), (8), (9), (10) and (11). However, as, in the preparation of illumination projects, the illumination has to be determined for various points of the space considered, the repeated calculation becomes somewhat tedious. The work can be considerably simplified by using the diagrams of Figs. 7 and 8.

Fig. 7 gives the curves of C_1 plotted against $\sqrt{Y^2 + Z^2} = \rho$ for various values of X, C_1 being defined as

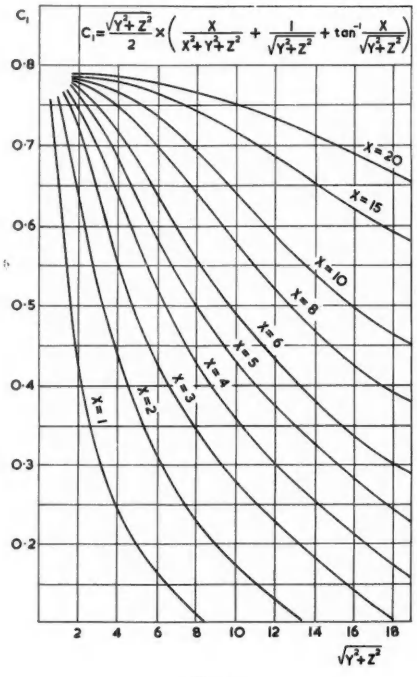


Fig. 7

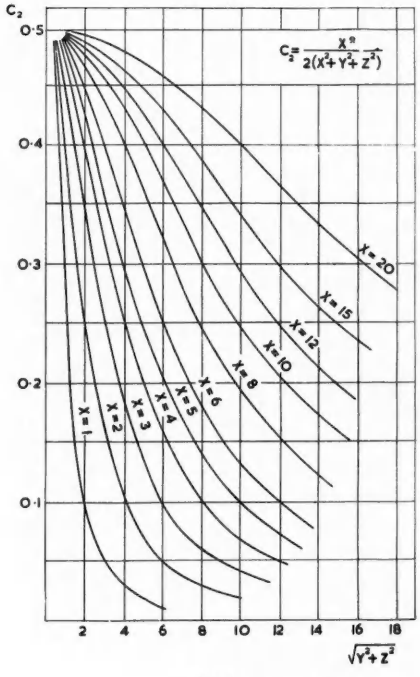


Fig 8

$$C_1 = \frac{\rho}{2}\left[\frac{X}{X^2+\rho^2} + \frac{1}{\rho}\tan^{-1}(X/\rho)\right]$$

so that, for the case of a *tubular* source, the illumination of a small area dA, situated in a parallel plane, is given by

$$E = \Phi_1 C_1/(\pi^2 Z) = 10^4\,\sigma\,dC_1/Z$$

whereas for a *luminous strip* the illumination of dA in a parallel plane is

$$E = \Phi_1 C_1/(\pi\rho) = 10^4\,\sigma\,C_1\,d/\rho.$$

It should be noted that the source of length X is situated in the semi-space for which x assumes positive values. If the source extends into the space where $x < 0$, the value of E ($x < 0$) should be determined separately and added to that for E ($x > 0$).

The illumination of dA in a perpendicular plane, in the case of a *tubular* source, is given by

$$E = \Phi_1 C_2/(\pi^2 Y) = 10^4\,\sigma\,C_2\,d/Y$$

and the expression for a *luminous strip* is

$$E = \Phi_1 C_2/(\pi Y) = 10^4\,\sigma\,C_2\,d/Y,$$

C_2 being defined as

$$C_2 = X^2/[2(X^2 + Y^2 + Z^2)].$$

The curves for C_2 plotted against $\sqrt{Y^2 + Z^2} = \rho$ are given in Fig. 7.

The above equations and diagrams give the value of the illumination in lux (i.e., lumen/m²), when the lengths are measured in metres, the flux being in lumens, and the brightness in stilbs (1 stilb = 1 Hefner candle/cm² = 0·9 international candle/cm²).

SWITZERLAND

The Sound Waves Generated by a Particle at Supersonic Speed

By M. H. MARTIN and G. B. JACKSON. (From *Schweizer Archiv*, Vol. 16, No. 4, April, 1950, pp. 114-119, 4 illustrations.)

In this article the sound waves created by a particle initially moving at supersonic speed are investigated for the cases of curvilinear motion and motion subject to gravity and air resistance. The three-dimensional case is also considered.

I. RECTILINEAR MOTION

A PARTICLE moving with a constant speed v along a horizontal straight line and passing through a point P of its trajectory at a time $t = t_0$ creates a spherical sound wave which expands uniformly from P with the constant speed of sound G.

When $t = t_1$, the particle is at Q, having covered the distance $s = \overline{PQ} = vt = v\,(t_1 - t_0)$. The wave from P has expanded into a circle of radius $R = Gt$. If the speed is supersonic, ($v > G$), then Q is outside the circle $C\,(R)$. Drawing the tangents from Q to $C\,(R)$ we have

$$\sin\alpha = R/\overline{PQ} = G/v$$

This determines the *Mach* angle α between a tangent and the trajectory (i.e., the locus of the centres of the circles $C\,(R)$).

If the particle is *decelerating* and $vt < Gt$, Q will be inside of $C\,(R)$. The wave contour has then a blunt vertex and the wave fronts or envelopes of the circles appear convex to an observer in front of the waves. The direction of the sound, however, will depend on the observer's position in the plane.

If the particle is *accelerating*, the wave front appears to be concave to an observer in front of the wave. The wave front will then develop singularities, and an observer will hear the sound from two or more distinct sources, either simultaneously or at different times.

2. CURVILINEAR MOTION

The motion of a particle moving in a vertical plane at a supersonic speed v (not necessarily constant) is determined by

$$x = x_0(s),\quad y = y_0(s) \quad .. \quad .. \quad (1)$$

where s = arc length of trajectory from the origin to the point $P_0\,(x_0, y_0)$.

Let the x-axis be directed horizontally, and the y-axis vertically downwards. The particle will have reached a point $Q_0\,(S)$ farther along its trajectory, after a time

$$t = \int_s^S \frac{ds}{v} \quad .. \quad .. \quad (2)$$

Then, since the radius of the sound circle for P_0 is $R = Gt$,

$$dR/ds = -G/v = -\sin\alpha \quad .. \quad .. \quad (3)$$

We consider the wave front, which is the envelope of the sound circles at points P_0 and which is, therefore, tangent to each such circle at a point $P\,(x, y)$ on the positive side of the trajectory. If θ and φ are the slope angles of the trajectory and the envelope, respectively, then (see Fig. 1)

$$\left.\begin{aligned} x - x_0 &= -R\sin\varphi \\ y - y_0 &= R\cos\varphi \end{aligned}\right\} \quad .. \quad .. \quad (4)$$

and

$$\dot{x}_0 = \cos\theta,\ \dot{y}_0 = \sin\theta \quad .. \quad .. \quad (5)$$

the dot denoting differentiation with respect to s.

The equation of the sound circle for the point P_0 is

$$C(R) = (x - x_0)^2 + (y - y_0)^2 - R^2 = 0 \quad .. \quad (6)$$

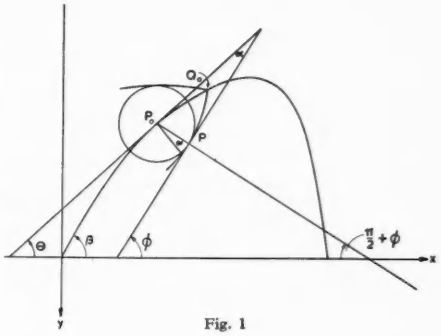


Fig. 1

then $\dot{C}/2 = (x - x_0)\dot{x}_0 + (y - y_0)\dot{y}_0 + R\dot{R} = 0$

The envelope is determined by means of $C = 0$ and $\dot{C} = 0$, and these, coupled with eqs. (3), (4) and (5) give

$$\sin(\theta - \varphi) = \sin\alpha$$

Since $\alpha < \pi/2$ and $\theta - \varphi < \pi/2$ for points P on the positive side of the trajectory, we have

$$\theta - \varphi = \alpha \quad .. \quad .. \quad .. \quad (7)$$

Therefore

$$\dot{\varphi} = \frac{1}{\rho} - \dot{\alpha} \quad .. \quad .. \quad (8)$$

where $1/\rho = d\theta/ds$ = curvature of the trajectory.

Therefore, according as $\dot{\varphi}$ is negative or positive on the trajectory, the sound wave generated by a particle moving at supersonic speed on a curvilinear path is convex or concave to an observer in front of it and on the positive side of the trajectory. (When $\dot{\varphi} < 0$ the wave front will be concave when it is sufficiently close to the trajectory, since at greater distances singularities will develop which affect the wave front.) Thus, for the rectilinear motion of an accelerating particle, $1/\rho = 0$ and $\dot{\alpha} < 0$ (concave wave front), and for a decelerating particle, $1/\rho = 0$ and $\dot{\alpha} > 0$ (convex wave front).

3. TRAJECTORY UNDER GRAVITY AND AIR RESISTANCE

If the particle velocity were constant, we would have $\dot{\alpha} = 0$ and by eq. (8) $\dot{\varphi} = 1/\rho$. As $1/\rho$ is generally positive for curves involved in gravitational motion, the result would be a concave wave front. However, the velocity of the particle is slowed down by air resistance, which thus tends to make the wave front convex. Furthermore, gravity itself tends to decelerate or accelerate the particle according as it is rising or falling.

The equations of motion of the particle are, therefore,

$$\left.\begin{aligned} d^2x/dt^2 &= -f(v)\cos\theta \\ d^2y/dt^2 &= g - f(v)\sin\theta \end{aligned}\right\} \quad .. \quad (9)$$

where θ = slope angle of the trajectory, g = gravity acceleration, and $f(v)$ = acceleration due to air resistance.

With regard to $f(v)$ it is assumed that (1) $f(v)$ is only a function of v and not of altitude; (2) $f(v)$ is continuous and positive for $v > 0$, and (3) $f(v)/v$ is a monotone increasing function of v for $v > 0$. Furthermore, the *limiting velocity* will be defined as the velocity v_1 for which $f(v_1) = g$, so that if the body is falling vertically ($\theta = \pi/2$), then $d^2y/dt^2 = 0$.

According to Levi-Cività the trajectory then has the following properties:—(1) If the initial value of θ is $\theta(t = 0) = \beta > \pi/2$, then $\beta < \theta < \pi/2$; (2) $1/\rho > 0$; and (3) the trajectory has a vertical asymptote. The slope angle θ thus starts at a value β and increases steadily towards $\pi/2$, approaching $\pi/2$ as the trajectory approaches the asymptote. We may thus substitute:

$$dx/dt = v\cos\theta$$
$$dy/dt = v\sin\theta$$

and eliminate t from eqs. (9), so that

$$dv/d\theta = [v(g\sin\theta - f(v)]/(g\cos\theta) \quad .. \quad (10)$$

Then, since $G = v\sin\alpha$, differentiation with respect to s and subsequent substitution of $\rho d\theta = ds$ gives:

$$\dot{v}\sin\alpha + v\cos\alpha\,\dot{\alpha} = 0$$

hence

$$\dot{\alpha} = -\frac{\tan\alpha}{\rho}\frac{d}{d\theta}(\log v)$$

Therefore, from this equation and eqs. (7) and (10), we obtain

$$\frac{1}{\rho} - \frac{d\alpha}{ds} = \frac{\tan\alpha}{\rho\cos\theta}\left[\frac{\cos\alpha}{\sin\alpha} - \frac{f(v)}{g}\right]$$
$$= \frac{v\tan\alpha}{\rho g\cos\theta}\left[\frac{g\cos\varphi}{G} - \frac{f(v)}{v}\right]$$

Since $1/\rho > 0$, and by the definition of α, the first factor is positive, hence

$$\frac{1}{\rho} - \dot{\alpha} < \frac{v\tan\alpha}{g\rho\cos\theta}\left[\frac{g}{G} - \frac{f(v)}{v}\right] \quad .. \quad (11)$$

and for all values $v > v_1$:

$$f(v)/v > f(v_1)/v_1 \quad g/v_1 \quad .. \quad .. \quad (12)$$

Substitution of (12) in (11) yields the relation

$$\frac{1}{\rho} - \dot{\alpha} < \frac{v\tan\alpha}{\rho\cos\theta}\left[\frac{1}{G} - \frac{1}{v}\right]$$

If it be assumed that the limiting velocity does not exceed the speed of sound ($v_1 < G$), it follows that $(1/\rho) - \dot{\alpha} < 0$, hence the sound wave front generated on the positive (concave) side of the trajectory is convex to an observer in front of the wave and passes each position of the plane at most once.

4. SOUND WAVES IN SPACE

In the three-dimensional case, the sound waves generated along the trajectory are spheres instead of circles. Adding a third (horizontal) dimension, eq. (6) becomes

$$(x - x_0)^2 + (y - y_0)^2 + z^2 = R^2$$

and the points of the envelope satisfy

$$(x - x_0)\dot{x}_0 + (y - y_0)\dot{y}_0 + R\dot{R} = 0$$

which is the equation of a plane perpendicular to the vector $(\dot{x}_0, \dot{y}_0, 0)$ and tangent to the trajectory at P_0. The points P of the sphere on the envelope are thus points of a circle in a plane perpendicular to the tangent at P_0. Thus all the rays P_0P make the same angle with the tangent at P_0, and this angle is $(\pi/2) - \alpha$. The "sound rays" therefore constitute a cone with a vertex P_0 and a semi vertex angle of $(\pi/2) - \alpha$.

It can be shown that the most likely place for singularities to develop in the wave front is directly under the arch of the trajectory, and that if they do not develop there, they cannot develop elsewhere. Furthermore, in the case of a particle moving subject to air resistance and to constant gravitational attraction, if $v\,(t = 0) > G$ and $v_1 < G$, and $f(v)$ is defined as in Section 3, then there is only one sound wave passing through any given point in space, and the observer at this point will hear the sound from a uniquely determined direction. However, if throughout the trajectory $v > G$, and if the initial velocity has a component vertically upwards, the sound wave generated by the particle cannot remain free from singularities.

If the motion is initially supersonic, but does not remain so throughout the motion, although $v_1 > G$, the velocity starts supersonic, drops to a subsonic minimum and then increases again to become supersonic once more. The hodograph equation then shows that the velocity decreases monotonically to a minimum and then increases monotonically to the limiting velocity v_1. From this it follows that over the second interval (where $v > G$), $dv/ds > 0$, hence $d\alpha/ds < 0$. Since on the entire trajectory $1/\rho > 0$, we have $1/\rho - d\alpha/ds > 0$ which shows that the wave fronts are concave and will develop singularities. It is, therefore, not possible in this case to obtain waves always free from singularities.

REFERENCES

LEVI-CIVITÀ: *Meccanica razionale*, Vol. 2, Pt. 1, pp. 115-132.

SIACCI: *Ballistica*, 2nd ed., 1888.

Impact, Tensile and Hardness Tests on some Ferrous Alloys and Weld Deposits at Low Temperatures

By T. FUKUROI, G. MONNA, N. ISHII, and Y. OKAMATSU. (From *Science Reports of the Research Institutes, Tohoku University*, Series A, Vol. I, No. 2, pp. 101-105, 7 illustrations.)

ALTHOUGH austenitic stainless steels show the best properties for use at low temperatures, it is sometimes important to use cheaper, lower-alloyed steels within certain limited temperature ranges. Investigations at sub-zero temperatures have, therefore, been carried out on the following steels (only the main constituents are given):

(1) Mild steel, 0·133 C, 0·52 Mn, 0·06 Si, 0·04 S;
(2) Low C-steel, 0·125 C, 0·55 Mn;
(3) Cr-Mo steel, 0·32 C, 2·5 Cr, 0·36 Mo, 1·0 Cu, 0·55 Mn;
(4) Cr-Mn austenitic steel, 0·32 C, 17·3 Mn, 11·7 Cr, 2·6 Si;
(5) Welding rod for (3), 0·25 C, 1·0 Cr, 0·3 Mo, 0·6 Mn, 0·35 Si;
(6) Welding rod for (4), 0·08 C, 16·2 Mn, 15·5 Cr, 1·1 Cu, 0·4 Si.

The welding rods for steels (1) and (2) had the same composition as the parent material.

The following temperatures were chosen:

− 195·5 °C — liquid nitrogen bath;
− 150 °C — pentane bath cooled with liquid nitrogen;
− 120 °C — pentane bath cooled with liquid nitrogen;
− 100 °C — pentane bath cooled with liquid nitrogen;
− 78·5 °C — alcohol bath cooled with liquid nitrogen;
− 50 °C — alcohol bath cooled with liquid nitrogen;
0 °C — ice bath.

The bath temperatures were controlled automatically to within ± 0·05° C.

Impact Tests

Fig. 1 indicates the arrangement of the test specimen for welded parts. The specimens were milled, annealed one hour at 900° C, cooled, annealed one hour at 850° C, quenched in oil, tempered at 650° C for two hours, and

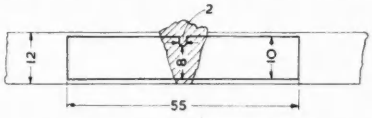


Fig. 1. **Position of Charpy impact test specimen in welded plate.**

finally finish-ground. They were then kept in the bath for 30 minutes and tested within 5 seconds of their removal from the bath. In order that its temperature rise on the testing machine might be minimised, each specimen was wrapped in thin cellophane sheet. The temperature rise was then only a few degrees, even at the lowest temperatures. Three tests were taken at each temperature and the average value recorded. Figs. 2 to 5 show the following results: Mild steel and Cr-Mo steel are unsuitable for use at low temperatures. Low carbon steel plate can be used down to about — 80 °C, but the welded structure of this material is brittle throughout the range of sub-zero temperatures. The austenitic steel can be used at all temperatures.

Tensile Tests

The specimens were 5 mm in diameter (0·2 in.) and were tested in the cooling bath, the stress-strain diagram being recorded automatically. The results are given in Table I.

The austenitic steel again shows the best results. The Cr-Mo steel has a small elongation and breaks in a brittle fashion. The low carbon steel remains ductile throughout, but the mild steel shows a tendency to brittleness.

TABLE I.

Steel	Test temperature °C	Lower yield point tsi	Ultimate strength tsi	Elongation per cent
Mild Steel ..	+ 25	22·15	31·1	24·9
	— 100	28·15	37·6	31·4
	— 196	54·1	62·4	3·6
Low Carbon Steel	+ 25	18·35	24·5	29·7
	— 100	29·65	32·0	32·8
	— 150	34·9	38·1	34·5
	— 196	50·7	51·7	16·0
Cr-Mo Steel ..	+ 25		50·4	11·2
	— 100	no yield	61·1	14·6
	— 150	point	66·9	12·0
	— 196		69·4	4·9
Austenitic Cr-Mn Steel	+ 25		52·8	39·4
	— 100	no yield	68·9	30·2
	— 150	point	77·4	29·8
	— 196		71·9	20·6

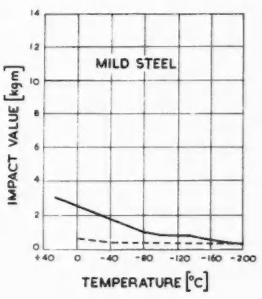


Fig. 2

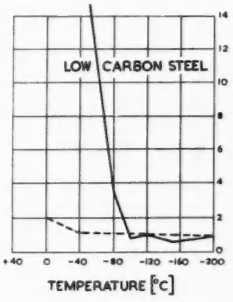


Fig. 3

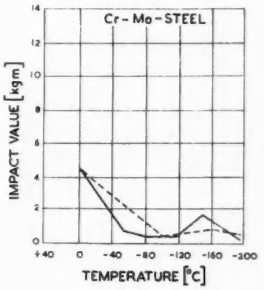


Fig. 4

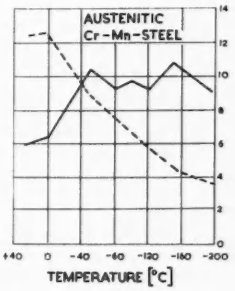


Fig. 5

Figs. 2 to 5. **Impact test values at various sub-zero temperatures.**
Full lines show test values for the parent plate, dotted lines the values for welded specimens.

Hardness Tests

As a check, hardness tests were taken on one side of the impact test specimens at room temperature. A Brinell machine was used with a 5 mm ball and 750 kg load held for 30 seconds. The average Brinell values

were found to be:

Mild Steel:	Base metal	145,	Weld	132;
Low C-Steel:	,,	,,	129,	,,	129;
Cr-Mo-Steel:	,,	,,	245,	,,	249;
Austenitic Cr-Mn-Steel:	,,	,,	298,	,,	250.

Conclusions

The austenitic steel is tough down to the temperature of liquid nitrogen, both as a plate of base material and as a welded structure. It can be used as a structural material at low temperatures even where severe vibrations and shock are to be expected. The low carbon steel can be used as a plate of base material down to — 80 °C and for less severe shock conditions. The impact performance of welded structures of low carbon steel can be improved if a highly alloyed Cr-Mn welding rod is used.

GERMANY

The Sonic Barrier in Centrifugal and Axial-Flow Compressors

By C. PFLEIDERER. (From *Zeitschrift des VDI*, Vol. 92, No. 6, February 21, 1950, pp. 129-133, 4 illustrations, and No. 16, June 1, 1950, pp. 406-407.)

High air velocities in compressors are essential for maximum performance and efficiency, but the sonic barrier has been found to set a limit to improvements obtainable. Well-known for his classical book on pump and compressor design, the author has recently developed a simple practical method of obtaining optimum conditions. An analogy is established between compression shock phenomena due to supersonic speeds in centrifugal compressors and cavitation phenomena in centrifugal pumps. The latter problem will be dealt with in a future article.

IN modern engine design, and particularly in gas turbine design, it is important to have compressors giving maximum head per stage so that the number of stages may be reduced to a minimum. The efficiency of any machine dealing with fluids generally, increases with increasing Reynolds number, since friction decreases, but this only applies until we approach the velocity of sound. In his compressor lay-out, the designer must, therefore, keep the maximum velocity near the velocity of sound and must obtain as high a head as possible without exceeding this limit. In the following, a rather simple method of calculation for these optimum conditions will be developed; it applies to axial-flow and centrifugal compressors with and without inlet guide vanes.

The velocity of sound is

$$v_s = \sqrt{g\gamma pv} = \sqrt{g\gamma RT} \quad .. \quad (1)$$

where $g = 32{\cdot}2$ ft/sec², γ = ratio of specific heats, p = pressure in lb/ft², v = specific volume in cu ft/lb, R = gas constant in ft-lb-Fahrenheit units, $T = t + 460$ and t = temperature of air in °F.

Taking $R = 96$ and $\gamma = 1{\cdot}4$, we have for dry air

$$v_s = 65{\cdot}8\sqrt{t + 460} \quad \text{[fps]} \quad .. \quad (2)$$

for air of medium humidity

$$v_s = 66{\cdot}4\sqrt{t + 460} \quad \text{[fps]} \quad .. \quad (3)$$

Supersonic velocity leads to compression shock at points of retarding gas flow, and hence to a similar fall in efficiency as is caused by cavitation in pumps. Turbines are less sensitive to this effect, since the flow accelerates at nearly all points.

Velocity peaks occur locally at points where, in the case of pumps, danger of cavitation would arise. Thus they do not occur at points of increased pressure. The most dangerous points are usually just behind the suction edges of the impeller, at the greatest radius of entry to the blades, i.e. at the points a_1 of Figs. 1 and 2, where the relative velocity is highest. This velocity can be calculated from

$$V_{r^2\,\max} = (1 + \lambda)\, V_{ra}^2 \quad .. \quad .. \quad (4)$$

where V_{ra} is the relative velocity at entrance to the blade at point a_1. If $V_{r\,\max} = v_s$ be the maximum permissible value, then the Mach number V_{ra}/v_s at inlet is determined by the assumed λ-value. Provided the outer wall at point a_1 is not too strongly curved, λ depends on the shape of the leading edge, the number of impeller blades and the Reynolds number only. For blades of constant thickness, the shape of the leading edge is actually less important, because of viscosity effects, than frictionless flow in tests is likely to show.[1] Hence values of $\lambda = 0{\cdot}2$ to $0{\cdot}3$ may be used. For axial-flow compressors, the shape of the entire blade is important, but from the analogy of cavitation in axial-flow pumps, we may deduce a good average value of $\lambda = 0{\cdot}25$. The volume expansion at points of localised supersonic flow is not covered by this analogy, but is unimportant at the leading blade edge[2]. Moreover, the designer is interested mainly in compressor efficiency, and this begins to drop only when compression shocks are already fairly extensive. Theoretical λ-values, or values derived from wind tunnel tests, are, therefore, likely to be too high. Furthermore, dangerous points are more localised on rotating blades than on stationary test blades. Experience shows that a Mach number of $0{\cdot}895$ at blade inlet, i.e., a λ-value of $0{\cdot}25$, is admissible. Axial blades with wide pitch and simply curved radial blades with an axial leading edge are more sensitive to cavitation and may, by analogy, require a higher λ-value.

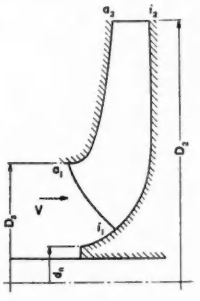


Fig. 1 (left). **General form of an impeller.**

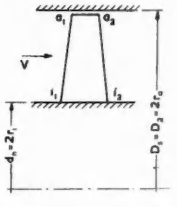


Fig. 2 (right). **Axial rotor blading as an extreme form of the impeller of** Fig. 1 ($D_s = D_2 = 2r_a$).

The maximum velocity of eq. (4) will usually be exceeded at the impeller outlet. However, the temperature is higher at the outlet and the diffuser vanes are often at a distance from the impeller outlet so that sonic velocities are unlikely to occur in the diffuser vanes. Even if they do, their influence on efficiency is less pronounced than at the impeller inlets.[5] With axial-flow compressors, the absolute outlet velocity is usually too small for supersonic speeds to occur in the guide vanes. Here, the relative inlet velocity has a much more pronounced effect, and the speeds of these

compressors are often limited, not by centrifugal stresses but by the approach to sonic velocities. We therefore consider only the outermost point a_1 of the blade inlet, where supersonic velocities may be expected to occur first.

Air entry without inlet guide vanes, purely radial or axial.

If we assume that the air velocity increases from zero before compressor inlet (initial state denoted by suffix g) to V at blade inlet, the volumetric flow at blade inlet will be approximately

$$Q = Q_g \left[1 + \left(\frac{V}{v_s} \right)^2 \right] = Q_g \left[1 + \left(\frac{Q}{A v_s} \right)^2 \right] \text{ [cfs]} \quad (5)$$

where Q_g is the quantity per second taken from surrounding air, $A = Q/V$ the cross-section at blade inlet. For $V/v_s \leqslant 0{\cdot}5$, we may use the theoretical v_s-value of the free air before compressor inlet; for $0{\cdot}5 < V/v_s \leqslant 0{\cdot}8$, the quadratic eq. (5) still holds if, instead of v_s, we introduce

$$v_{cr} = \sqrt{2g \frac{\gamma}{\gamma + 1} R T_g} = 60{\cdot}05 \sqrt{t_g + 460} \quad .. \quad (6)$$

i.e., the critical air velocity for adiabatic expansion from the initial state. However, since $V_r > V$, the value V/v_s will, in general, have to be limited to 0·6 if sonic speeds are to be avoided. The volume increase $(Q\text{-}Q_g)/Q_g$ from compressor inlet to blade inlet is then still 18 per cent and thus merits further attention.

Let β_{oa} be the impeller inlet angle at a_1, and v_a the peripheral impeller velocity at a_1, then, for entry of air without whirl, $\tan \beta_{oa} = V/v_a$ from inlet diagram, and

$$Q = A v_a \tan \beta_{oa} = A \frac{\pi D_s n}{60} \tan \beta_{oa} \quad \text{[cfs]} \quad (7)$$

Now,

$$A = \frac{\pi}{4} D_s^2 k \quad \text{[sq ft]} \quad .. \quad (8)$$

where the factor $k = 1 - (d_n/D_s)^2$ takes account of the reduction of cross-sectional area, due to the hub (Fig. 1). Eliminating D_s from eqs. (7) and (8) and solving for A, we obtain

$$A = \left(30 \sqrt{\frac{k}{\pi}} \frac{Q}{n \tan \beta_{oa}} \right)^{3/2} \quad .. \quad (9)$$

If we introduce this value into eq. (5) and solve the resulting cubic equation (by substituting $Q^{\frac{1}{3}} = 1/x$) we find a real root leading to the expression

$$\frac{Q - Q_g}{Q} = \frac{3}{2} B^{\frac{1}{3}} \left[(\sqrt{1 + B} + 1)^{\frac{1}{3}} - (\sqrt{1 + B} - 1)^{\frac{1}{3}} \right] \quad (10)$$

where

$$B = \frac{1}{54} \left(\frac{\pi}{30^2} \frac{n^2 Q_g}{k v_s^3} \right)^2 \tan^4 \beta_{oa} \quad .. \quad (11)$$

Since, in practice, $\beta_{oa} < 45°$, B is always small as compared with unity so that, approximately,

$$\frac{Q_g}{Q} = 1 - 3 \left(\frac{B}{4} \right)^{\frac{1}{3}} \quad .. \quad .. \quad (12)$$

We can apply these equations once β_{oa} and n are known, but these values must themselves be so chosen that *optimum conditions* just below sonic speeds are obtained. The optimum value of V_{ra} is thus reached when

$$V_r^2 \max = v_s^2 = (1 + \lambda) V_{ra}^2 \quad .. \quad (13)$$

The inlet diagram shows that

$$V_{ra} = \frac{v_a}{\cos \beta_{oa}} = \frac{\pi D_s n}{60 \cos \beta_{oa}} \quad .. \quad .. \quad (14)$$

If we eliminate first D_s by means of eq. (8), then A of eq. (8) by means of eq. (9), and introduce the resulting expression into eq. (13), we find

$$v_s^2 = (1 + \lambda) \left(\frac{\pi}{30^2} \frac{n^2 Q}{k \sin \beta_{oa} \cos^2 \beta_{oa}} \right)^{2/3}$$

hence the following relationship, which is valid at the sound barrier:

$$\frac{n^2 Q}{k v_s^3} = - \frac{30^2}{\pi (1 + \lambda)^{3/2}} \sin \beta_{oa} \cos^2 \beta_{oa} \quad .. \quad (15)$$

Since Q_g, and not Q, is usually given in practical problems, we may finally put $V = V_{ra} \sin \beta_{oa}$, combine this with eq. (13) so that

$$\left(\frac{V}{v_s} \right)^2 = \frac{1}{1 + \lambda} \sin^2 \beta_{oa} \quad .. \quad .. \quad (16)$$

If we introduce eq. (16) into eq. (5), and the resulting expression for Q into eq. (15), we obtain

$$\frac{n^2 Q_g}{k v_s^3} = - \frac{30^2}{\pi (1 + \lambda)^{3/2}} \frac{\sin \beta_{oa} \cos^2 \beta_{oa}}{1 + \frac{1}{2(1 + \lambda)} \sin^2 \beta_{oa}} \quad (17)$$

The left-hand sides of eqs. (15) and (17) are dimensionless and may be considered as factors indicating how far the impeller speed can be increased within the subsonic region. The lower curves of Fig. 3 show these factors as functions of the inlet angle β_{oa} for a λ-value of 0·25. Optimum conditions are obtained at the maximum of these curves, i.e., with inlet angles of 32° 10′, and 35° 20′ respectively. These optimum angles are practically independent of λ, as differentiation of eqs. (15) and (17) shows; they only apply to the inlet angle at the outer edge of the impeller blade, as the angle increases towards the inside. The more practical value $n^2 Q_g / v_s^3$ may be called the "subsonic factor" and can be read off Fig. 3 after multiplication by k. A low k-value, i.e., a large hub diameter, thus diminishes the applicable speed range in the subsonic region. For a given design with a specific speed $n_s = n Q^{\frac{1}{2}} / H^{\frac{3}{4}}$, the factor $n^2 Q / v_s^3 = n_s^3 H^{3/2} / v_s^3$ determines the optainable discharge head as well.

In designing the compressor, we shall first choose β_{oa} near the optimum value 32° 10′. From Fig. 3, the corresponding value of $n^2 Q_g / k v_s^3$ can then be found.

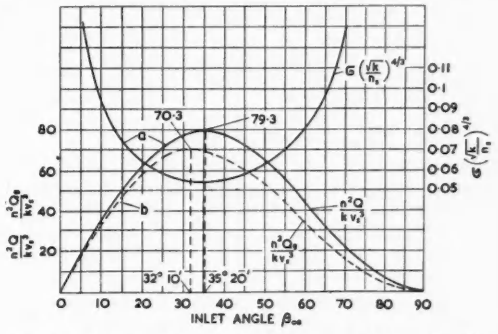


Fig. 3. **Representation of the limiting condition at sonic speed as a function of the angle β_{oa} at blade inlet.**

(a) Volumetric flow remaining constant throughout inlet passage;

(b) Volumetric flow increases, from Q_g to Q, in inlet passage. Curves with maximum represent the "subsonic factor," $n^2 Q / v_s^3$. Curve with minimum represents the "supersonic sensitivity factor," $\sigma = v_s^2 / 2gH$.

The critical values of the curve may, if necessary, be exceeded[4] since any resulting supersonic velocities would be purely local; centrifugal stresses must, however, be considered. We now assume a ratio d_n/D_s and calculate the factor k of eq. (8). The finite blade thickness may be considered by choosing k slightly smaller than calculated. v_s is determined from the considerations mentioned before (following eq. (5)), Q_g is given, and n may thus be calculated from $n^2\,Q_g/kv_s^3$. D_s is then found from eqs. (13), (14), and Q from eqs. (16), (15). Conversely, Q_g can be calculated when Q is given. If, in centrifugal compressors, the blades are riveted in, D_{a1} may be slightly larger than D_s (see Fig. 1) and the "subsonic factor" must then be reduced accordingly. The head per stage does not enter into these calculations since we only consider the danger of supersonic speeds at a point near the leading blade edge, and the form of the whole blade influences the value of λ but slightly. The head will thus have to be determined from considerations of efficiency or maximum peripheral speed at impeller outlet, or by the permissible surge figure in axial-flow compressors. However, if the geometrical shape of the impeller is also determined by factors outside these calculations, the discharge head per stage will enter into the choice of optimum conditions. This can best be followed if we introduce a "supersonic sensitivity factor" $\sigma = v_s^2/2gH$ (corresponding to Thomas' coefficient for cavitation in pumps), eliminate $H = (n^2Q/n_s^2)^{2/3}$, and enter eq. (15) with the resulting expression. The coefficient thus obtained

$$\sigma\left(\frac{\sqrt{k}}{n_s}\right)^{4/3} = \frac{1+\lambda}{2g}\,\frac{\pi}{30^2}\left[\frac{1}{\sin\beta_{oa}\cos^2\beta_{oa}}\right]^{2/3} \qquad (18)$$

is also shown in Fig. 3, and has an optimum value for $\beta_{oa} = 35^\circ\,20'$.

Numerical example. Design a multi-stage axial-flow compressor for a gas turbine, given $Q_g = 353$ cfs.

We first choose $\lambda = 0{\cdot}25$ and $\beta_{oa} = 32^\circ\,10'$ (optimum). From Fig. 3, or eq. (17), we then find $n^2\,Q_g/kv_s^3 = 70{\cdot}3$. For safety, we reduce this figure to 68. Choosing a blade ratio $l/r_a = 1/3$, we find $k = 1 - (2/3)^2 = 0{\cdot}556$. With $v_s = 1082$ fps, we thus obtain $n = 11{,}650$ rpm. Eqs. (13) and (14) now give $D_s = 2r_a = 1{\cdot}32$ ft, hence the blade length $l = r_a/3 = 2{\cdot}64$ inches. We also find the blade tip speed from eq. (14), $v_a = 807$ fps, the air velocity at blade inlet from eq. (16), $V = 508$ fps., and finally from eq. (5), $Q = 395$ cfs.

Air entry with inlet guide vanes, peripheral component.

Due to pressure drop in the inlet guide vanes, the quantity Q of air flowing increases with the absolute air velocity, which now has, in addition to $V = V_f$, a circumferential component V_w varying with the radius r. Over a radial element dr, the increase of Q is

$$dQ_k = dQ\left[1 + \frac{1}{2}\left(\frac{V_w}{v_s}\right)^2\right] = 2\pi r dr\;V_f\left[1 + \frac{1}{2}\left(\frac{K_o}{v_s\,r}\right)^2\right]$$

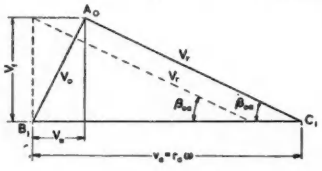


Fig. 4. Two inlet velocity triangles for equal approach to sonic velocity.

Assuming V_f and, in order to maintain equilibrium of flow, also $K_o = r\,V_w$ to be independent of r, we may integrate between the limits d_n and D_s, so that

$$Q_k = Q + \pi\,V_f\left(\frac{K_o}{v_s}\right)^2 \log_e\frac{D_s}{d_n} \qquad (19)$$

If $Q_k - Q$ is found to be of appreciable magnitude, the calculation must be corrected by assuming a correspondingly greater value of V_f. Friction in the inlet guide vanes has not been considered here. The preceding calculations may now easily be adapted for this case: We repeat the previous derivation of an optimum leading angle β_{oa} for the new assumption that a certain ratio $V_w/v_a = K_o/r_{a1}^2\,\omega$ must be maintained at point a_1. We then obtain the new coefficient

$$C^2\,\frac{n^2\,Q}{kv_s^3} = \frac{30^2}{\pi\,(1+\lambda)^{3/2}}\sin\beta_{oa}\cos^2\beta_{oa} \qquad (20)$$

where

$$C = 1 - \frac{K_o}{r_{a1}^2\,\omega} = 1 - \frac{V_w}{v_a} \qquad (21)$$

is constant according to assumption. The preceding exposition remains valid, therefore, provided we introduce k/C^2 instead of k. The angle of $35^\circ\,20'$ thus remains an optimum, and the optimum angle of $32^\circ\,10'$ is but slightly reduced by the volume increase according to eq. (19). The curves of Fig. 3 hold good if we multiply each value of the lower curves by C^2 or *change the rpm in the ratio* $1/C$. The inlet triangle for this case (Fig. 4) shows that V_f and V_{ra} remain unchanged. If we ignore the slight increase in Q, the wheel diameters, therefore, also remain unchanged.

Numerical example. The preceding axial-flow compressor is to be laid-out for a whirl component, in direction of rotation, of ratio $V_w/v_a = 0{\cdot}2$ at the leading blade tip.

We have $C = 1 - 0{\cdot}2 = 0{\cdot}8$. For the same sonic-speed conditions, the rotor must run at $11650/0{\cdot}8 = 14560$ rpm. Using this speed and the optimum angle $\beta_{oa} = 32^\circ\,10'$, and assuming the expected increase in Q to be small, we have the same wheel dimensions as before and find $v_a = 1010$ fps, $K_o = r_{a1}\,V_w = 0{\cdot}2\,r_{a1}\,v_a = 134$ ft²/sec. From eq. (19), we then obtain $Q_k = 405$ cfs, an increase of only 2·5 per cent, so that the calculation need not be repeated. This increase, however, requires that either the diameters or the angle β_{oa} be increased correspondingly, and in view of efficiency and costs, one would rather increase the blade inlet angle. Since the change is only small, the tip angle β_{oa} can be left unchanged and the inlet angle increased at the smaller radii.

K_o is positive and $C < 1$ if the inlet air velocity is given a (positive) whirl component in the direction of wheel rotation. The optimum speed n then increases with $1/C$. For a whirl velocity against the direction of rotation, the optimum speed n would decrease. It can be shown that the head per stage changes proportionally with n if the sonic-speed condition is adhered to. If, in our example, the same head as for entry without guide vanes had been used, the speed could have been reduced. Since, however, the optimum angle β_{oa} should be maintained, the meridian component V_f would then decrease and the wheel diameters would have to be increased.

REFERENCES

(1) E. Wolf, *Ing.-Arch.*, Vol. 4 (1933), pp. 521-544.
(2) E. Lamla, *Jahrb. Dtsch. Luftf. Forsch.* (1939), p.I 165. E. Lamla, *Jahrb. Dtsch. Luftf. Forsch.* (1940), p. I 26.
(3) A. Betz, *Z. VDI.*, Vol. 92 (1950), No. 9, pp. 201-206.
(4) S. Bogdanoff, N.A.C.A. Cascade Data for the Blade Design of High-Performance Axial-Flow Compressors, *J. Aeron. Sc.*, Vol. 15 (1948), pp. 89-95.
(5) R. J. Focke, *Ffrsch. Ing.-Wes.*, Vol. 16 (1949), pp. 43-50.

The Free-Piston Compressor and Gas Turbine Power Unit for Ship Propulsion

By A. AUGUSTIN-NORMAND. (From a Paper presented to *Association Technique Maritime et Aéronautique*, 1950, 24 pages, 11 illustrations.)

THE free-piston compressor and gas turbine unit has already been built for stationary power plant in France and is now being adapted for use on an 850-ton cargo vessel; smaller as well as larger power units for ship propulsion are being planned. The whole plant (Fig. 1) comprises two motor-compressor units *A* (see also Fig. 2) burning Diesel or even heavier fuel oils and generating the gas which drives the propulsion gas turbine *B*. Part of the motor-compressor exhaust gases is also used to drive a turbo-electric set for the auxiliary pumps and other ship installations.

The motor-compressor unit, Fig. 2, works on the two-stroke principle. On the outstroke, air is admitted through suction valves (6) into the interior of the two large side cylinders (2); on the instroke, this air is partly compressed and delivered through valves (7) into the central receiver (5) surrounding the motor cylinder (4) with its six fuel injectors arranged in a ring at the centre of the unit. Combustion of the air in the motor cylinder (4) drives the two piston units on the outstroke. Towards the end of this stroke, first the outlet ports (above (14)), then the scavenging ports (above (5)) are uncovered so that the gas is exhausted and the cylinder scavenged and re-filled with air from the receiver (5). The scavenging action thus follows the classical uniflow principle. The instroke finishes the pre-compression of the combustion air in the motor cylinder. At I.D.C., the compressed air in the motor cylinder provides a cushioning, energy-storing effect which helps to drive the free-piston unit over this dead-centre position. The two large air spaces at the outside of the two large pistons provide a similar energy-storing effect for the O.D.C. position and transfer the energy from the power outstroke to the working instroke; the pressure in these spaces is equalized by means of the tube (8). A special mechanism strictly synchronises the piston movements at each instant.

The power fluid driving the gas turbine consists partly of the exhaust gas and partly of the scavenging gas-air mixture, and has a temperature of 450 to 500° C, and a pressure of 42 to 50 psi. One compressor unit supplies sufficient gas to drive a 1100-hp gas turbine, but for marine use, the output has been restricted to 800 hp so that a large safety margin is obtained. The unit then runs at about 500 cycles per minute. Two units have been combined to feed the gas turbine running at 6000 to 11,000 rpm according to the power output required. The control of the output is particularly simple, since part of the exhaust gas may be led directly to the funnel without passing through the turbine. The turbine is also provided with a reversing wheel, and very easy and quick manoeuvrability is obtained if gas is fed into the turbine in such a manner that the forward and reverse torques are fully or almost fully balanced. The free-piston units need not, therefore, be stopped for reversing, and manoeuvring is much simpler than with a Diesel engine. The compressed-air bottles required for starting the compressor units can thus be much smaller than the bottles needed for a Diesel drive. Manoeuvrability is, in fact, as flexible as for a steam engine, whilst the overall design of the power plant is much simpler and lighter. Added

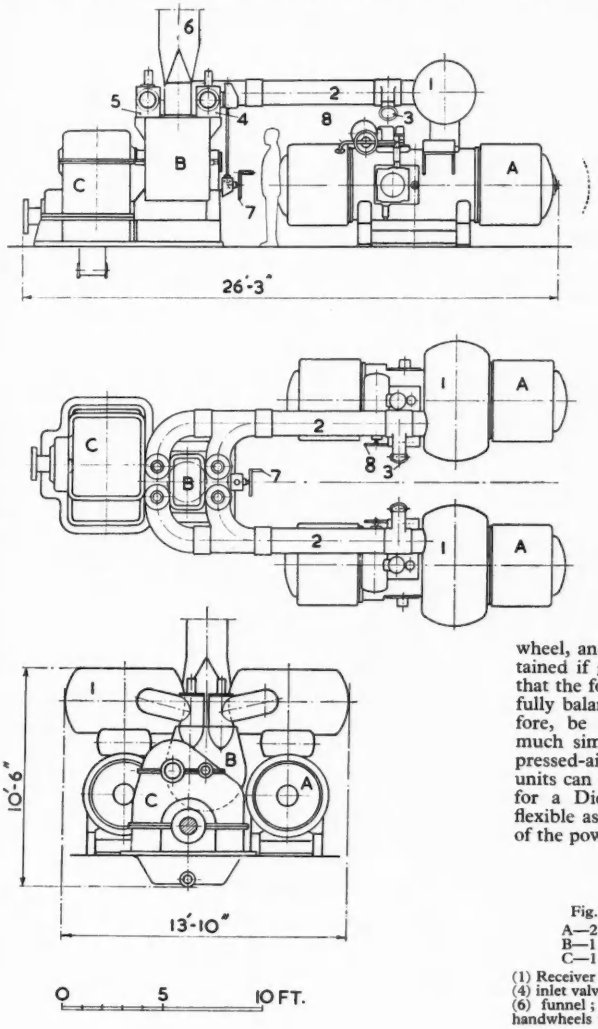


Fig. 1. **Marine power plant of 1600/1800 shp.**
A—2 gas generators, type GS-34.
B—1 gas turbine, 9000 rpm.
C—1 reduction gear, 9000/165 rpm.
(1) Receiver for exhaust gas; (2) exhaust gas pipes; (3) stop valves; (4) inlet valve to forward turbine; (5) inlet valve to reverse turbine; (6) funnel; (7) control and reversing handwheel; (8) starting handwheels for generators.

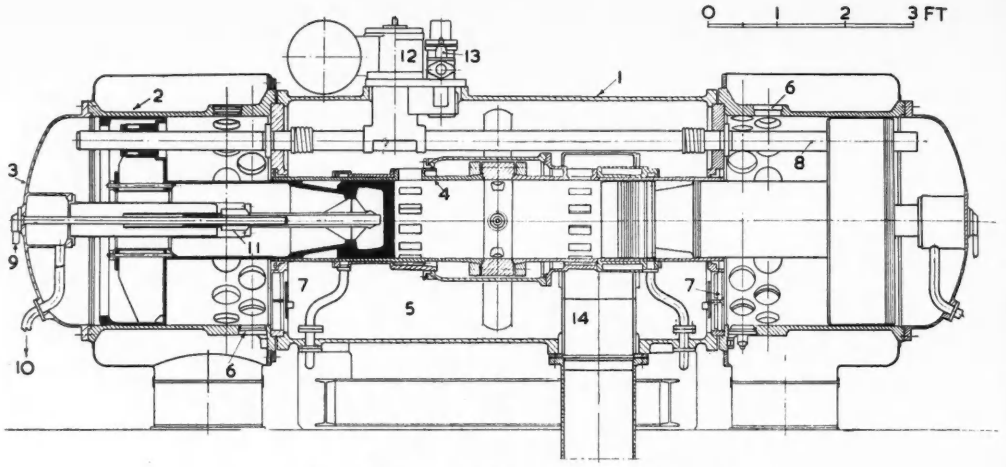


Fig. 2. **Free-piston compressor, Pescara-S.E.M.E., type GS-34.**
(1) Cylindrical housing; (2) compressor cylinder; (3) dished side cover; (4) motor cylinder; (5) receiver for scavenging air; (6) suction valves; (7) delivery valves; (8) guide tube; (9) cooling-oil inlet; (10) cooling-oil outlet; (11) packing gland; (12) starter; (13) governor; (14) exhaust gas conduit.

to this is the advantage that the reversing parts are not connected mechanically with the ship's drive, so that the engine runs extremely smoothly and without vibration. Maintenance is very easy if two compressor units are provided, since one can be repaired whilst the ship is kept running with the other unit. The design of the unit is so arranged that dismantling needs little space beyond that occupied by the unit itself. The GS-34 type compressor has an overall length of 13 ft 8 in. and only needs 2 ft of additional space for dismantling.

Accessories required are: one electrical pump and heat exchanger per compressor unit for the cooling-water in the cylinder jackets; one similar unit for the cooling-oil in the piston units; one sea-water pump for the heat exchangers; one lubricating pump and oil-cooler for the turbine and reduction gear; a pump, emergency pumps and purifier for the fuel oil; one starting air bottle of 14 cu ft capacity per compressor unit, at 1000 psi pressure. A comparison of the overall weight of the plant described with that of a comparable Diesel plant shows a considerable saving of weight. For a 800-hp drive, a Diesel unit requires about 88 lb/hp, the power unit described, with 2 compressor units, i.e., with 100 per cent power reserve, only 66 lb/hp, and the plant with one compressor unit only 44 lb/hp. For the overall plant, the saving in weight as compared with the Diesel unit is 13 per cent, and 25 per cent, respectively. The advantage would be still more pronounced for larger units. A 6000 hp Diesel drive, e.g., would require about 121 lb/hp whilst the gas turbine drive described can be reduced to 62 lb/hp. A considerable amount of space is also saved, and the weight can be more suitably distributed, since compressors and turbine unit are only connected by pipes. The fuel consumption is about the same as for Diesel engines.

The advantages of the free-piston compressor and gas turbine unit may thus be summarised as follows:—

(a) Saving of weight and bulk, better distribution of the weight, and easier adaptation to ships' requirements.
(b) Easier manoeuvrability. The compressor units need not be stopped during manoeuvring, hence less starting air is used and smaller starting bottles are needed.
(c) The compressor units are separate and can, therefore, be maintained more easily, even during running of the rest of the plant. Moreover, the compressors can easily be dismantled, and quiet running leads to less wear of moving parts.
(d) Perfectly balanced units, no vibration.
(e) Relatively low gas temperatures, no silencers required.
(f) The plant lends itself particularly well to standardisation of the different units.

AEROSOL INDICATOR

(*Continued from page* 310.)

The particles which can be observed with this apparatus are of the size group which is of particular interest, according to the above discussion. The apparatus does not determine the nature of the particles in motion. In the cases considered here, the types of dust particles are usually known. Furthermore, no indication of the actual particle size is obtained, apart from the fact that large-size particles will appear with greater luminous intensity than the smaller ones. Finally, the effective volume appearing in the field of vision is a function of the particle size, with the result that the counting of the number of particles per unit volume of the sample of air tested will only be approximate. The focussing is, however, so adjusted that for counts of particles of nearly the same size, the observable volume in the air chamber is approximately 1/100th of a cubic centimetre. A content of 100 particles per cm^3 in the air sample will, therefore, on average, correspond to one single particle in the field of vision, 200 particles per cm^3 will give 2 particles, etc. An appreciation of the lower limit of particle sizes observable may be obtained from the fact that newly formed tobacco smoke particles, which have a diameter of some tenths of a μ, are distinctly visible in the apparatus. A certain amount of practice is, of course, required in order to make reliable observations and for an accurate interpretation of the results.

USE OF APPARATUS

With the light source switched on and the fan operating, large-size particles passing through the field of vision of the microscope will be observed as distinct light flashes or light beams. Smaller-size particles occurring in large quantities will be seen as slower or

(*Concluded on page* 326)

New Principles for Commutator Design and Manufacture

By F. L. LAUB. (From *Bulletin de l'Association Suisse des Electriciens*, Vol. 40, No. 25, 1949, pp. 988-1001, 8 illustrations.)

With the principles set forth in this article, it should be possible to build commutators which will retain their compactness even under unfavourable working conditions. The practical conclusions arrived at are based on an analysis of the elastic deformations of the main commutator components, and formulae are derived for determining the mechanical and thermal forces involved.

(*Concluded from August issue*).

The micanite cone caps are subjected to an additional compression. The axial projection of this compression for the two caps is

$$2s_c\, p_c''/(E_{mc} \sin \beta)$$

where s_c = cap thickness, E_{mc} = elasticity modulus of the mica under compression, and p_c'' = additional pressure due to longitudinal bar expansion. The force R producing the pressure p_c'' will be determined later on. Thus, the resultant load on the bolts in the hot commutator is $(\Sigma M + R)$, and

$$p_c'' = 2R/[Kq\,(m_1 + m_2) \sin \beta]$$

so that

$$2s_c p_c''/(E_{mc} \sin \beta) = 4\,Rs_c/[Kq\,(m_1 + m_2) \sin^2 \beta\, E_{mc}].$$

Let z = number of bolts, E_s = elasticity modulus of bolts, x = effective bolt length, i.e., length of reduced diameter y between the two threaded end portions. The additional elastic elongation of the bolts is then

$$4\,Rx/(zy^2\,\pi\,E_s).$$

As the bolts are subjected to a temperature rise, they also have a thermal elongation

$$x\alpha'''\,k'\,\Delta t,$$

where α''' = linear coefficient of expansion of the bolt material, and $k'\Delta t$ = temperature rise of the bolts, which is regarded as being the same as that of the Vee rings. The accuracy of this assumption for $k'\Delta t$ depends on the bolt arrangement. Thus, for instance, if the bolts are situated between the bars and the hub, they receive heat from the inner surface of the bars and reach higher temperatures, so that more favourable conditions are obtained than when the bolts are separated from the bars by the hub thickness, and are only heated by contact with the Vee rings. In order to make a conservative assessment, it is thus convenient to take the length x as the effective bolt length for thermal expansion. The total elongation of the bolt is then

$$4\,Rx/(zy^2\,\pi\,E_s) + x\alpha'''\,k'\Delta t.$$

This deformation is equal to the thermal expansion of the bars minus the axial projection of the shortening due to the compression of the micanite caps. (The radial deflection of the bars is so small that the corresponding shortening in the axial direction can be neglected.) Therefore,

$$l'\alpha\,(0{\cdot}3 + 0{\cdot}7k)\,\Delta t - 4Rs_c/KE_{mc}\,q\,(m_1 + m_2) \sin^2 \beta = x\alpha'''\,k'\Delta t + 4\,Rx/(zy^2\,\pi\,E_s),$$

E_{mc} denoting the elasticity modulus of mica under compression. Rearranging, we obtain

$$l'\alpha\,(0{\cdot}3 + 0{\cdot}7\,k)\Delta t - x\,\alpha'''\,k'\Delta t = 4\,R[x/(zy^2\pi E_s) + s_c/Kq\,E_{mc}\,(m_1 + m_2) \sin^2 \beta] \quad \text{(XII)}$$

For a first approximation, the second term on the right-hand side of eq. (XII), representing the compression of the cone caps, can be neglected.

This equation comprises the unknowns R, x y, z, α''' and E_s, for which suitable numerical values must be chosen so as to reduce R to a minimum. The effective bolt length x, which should be chosen as great as possible, is usually already fixed by the commutator length. To avoid obtaining excessively thin bolts, the number of bolts should be limited, taking also into consideration the maximum allowable pitch circle in the compression rings. In choosing the reduced bolt diameter y, a few trial calculations will be required, and it will be necessary to avoid the traditional tendency of using oversize dimensions, since the object of this calculation is to obtain tightening bolts with sufficient elasticity.

After having decided on the material for the bolts, the approximate value of R can be determined by means of eq. (XII), used in its simplified form, in which the term with s_c is omitted. The value obtained for R is then compared with ΣM to assess the percentage increase in the tightening load. The ratio $R/\Sigma M$ is useful as a figure of merit in assessing the designs of large-size commutators, particularly in cases where long bars are used.

Regarding the type of bolt material, a short discussion of eq. (XII) may be useful. If the two terms on the left-hand side were equal, R would be equal to zero, and the additional thermal stresses would be completely eliminated. The factor $(0{\cdot}3 + k)\,\Delta t$ represents the temperature at the midpoint of the dovetail height, which must always be greater than $k'\Delta t$, the temperature of the tightening bolts. Decreasing l' would reduce the value of the left-hand side of the equation, but it would also result in a decrease in the compactness of the commutator. More favourable results are possible by increasing the second term on the left-hand side, so that both α''' and $k'\Delta t$ will be higher. This requires that the bolts be made of a material with a coefficient of expansion greater than that of steel, and that they be situated as close as possible to the bars, for increased heat transmission through radiation. Moreover, no micanite cylinders should be inserted between the bars and the bolts, since this would prevent heat transmission.

On the right-hand side of eq. (XII), the term with s_c represents the axial compression of the conical caps. As this is a small effect, it is only noticeable in short commutators, but even with these it is hardly possible to obtain a substantial variation of R by varying the thickness s_c or the elasticity modulus E_{mc}. It is thus preferable to use the harder Indian Muscovite for the conical caps, since in many cases R reaches a very high value, and a high E_{mc} will then provide increased safety against permanent deformations. (In literature, frequently the opposite recommendation is made, stating that a "softer" mica is more suitable for the conical caps. It should be noted, however, that this recommendation applies to the flexibility of the micanite, and is justified in this respect. This flexibility is obtained by using a higher percentage of bond substance, and should not be confused with a reduction in hardness. Furthermore, Indian mica does not tend to flake so easily as Canadian phlogopite, and this is of importance for the uniformity of the caps.) The thickness s_c depends on the commutator size and the type of caps used, but in all cases the smallest permissible thickness should be specified, in order to obtain maximum uniformity.

The first term on the right-hand side of eq. (XII) includes the dimensions and the elasticity modulus of the bolts. It has already been mentioned that R can be appreciably reduced if the bolt material has a high thermal expansion coefficient. Moreover, if the material has an E value which is lower than that of

steel, but is nevertheless sufficiently hard and tough to ensure adequate resistance of the screw threads, the additional thermal stresses can be reduced most effectively.

In fact, a wide range of structural bronze materials is available with properties which amply fulfil the above requirements. Comparative data for phosphor bronze and standard good quality steel are given in the following table:—

	Steel	Phosphor bronze (hard), 89·5 % Cu and 10·5 % Sn
U.T.S. [kg/cm²] ..	6330–8790	7770
Proportionality limit [kg/cm²] ..	4570–6330	6398
Modulus of elasticity [kg/cm²] ..	$2{\cdot}1$–$2{\cdot}25 \times 10^6$	$0{\cdot}984 \times 10^6$
Linear expansion coefficient [per °C] ..	0·0000112*	0·0000173†

*U.S. Bureau of Standards, Scientific Paper No. 433.
†U.S. Bureau of Standards, Scientific Paper No. 410.

The advantages of using tightening bolts of hard phosphor bronze of the composition and quality given in this table will be illustrated by the following *example*. The commutator considered is the same as previously and its specification will be completed by the following data:—

$l = 38$ cm (mean bar length, taking account of dovetail notches); $l' = 35$ cm (length between centroids of dovetail end surfaces); $x = 40$ cm (effective length of tightening bolts); $s_c = 0{\cdot}2$ cm (thickness of micanite caps); $E_{mc} = 0{\cdot}47 \times 10^6$ kg/cm² (estimated compression modulus of Muscovite); $(m_1 + m_2) q = 6{\cdot}34$ cm² (area of both dovetail end surfaces of one bar); $\beta = 30°$ (dovetail angle); $\Delta t = 45°$ C; $k\Delta t = 43°$ C; $k'\Delta t = 35°$ C; $\alpha = 17 \times 10^{-6}$; α''' from above table.

Then $\Sigma M = K \tan \beta\ (p_i + p_e)\ (b_e - b_i)\ l/2 =$ 32,229 kg (from eq. (X)). For equation (XII), the following terms will be calculated:

$l' \alpha\ (0{\cdot}3 + 0{\cdot}7\ k)\ \Delta t = 0{\cdot}02594$ cm,

$4s_c/[K\ (m_1 + m_2)\ q\ E_{mc} \sin^2 \beta] = 0{\cdot}5008 \times 10^{-8}$ cm,

$0{\cdot}02594 - 40\alpha''' \times 35 = R\ [0{\cdot}5008 \times 10^{-8} + (4 \times 40/zy^2 \pi E_s)]$,

hence

$R = (0{\cdot}02594 - 1400\ \alpha''')/[0{\cdot}5008 \times 10^{-8} + (50{\cdot}9295/zy^2 E_s)]$.

For *steel bolts* this gives:

$\alpha''' = 11{\cdot}2 \times 10^{-6}$; $E_s = 2{\cdot}2 \times 10^6$; 18 bolts; $y = 1{\cdot}1$ cm.

$R = (0{\cdot}02594 - 0{\cdot}01568)/[(0{\cdot}5008 + 106{\cdot}2891) \times 10^{-8}]$ $= 9617{\cdot}0$ kg, and

$R/\Sigma M = 9617/32229 = 0{\cdot}2984 = 29{\cdot}84$ per cent.

Average maximum bolt stress $= 4\ (R + \Sigma M)/(zy^2\ \pi)$ $= 2446{\cdot}2$ kg/cm².

Proportionality limit for steel = 4570 to 6330 kg/cm². The safety factor is, therefore, 1·87 to 2·59.

For *bronze bolts*:

$\alpha''' = 17{\cdot}3 \times 10^{-6}$; E_b (instead of E_s) $= 0{\cdot}984 \times 10^6$; 18 bolts; $y = 1{\cdot}1$ cm.

$R = (0{\cdot}02594 - 0{\cdot}02422)/[(0{\cdot}5008 + 237{\cdot}6382) \times 10^{-8}]$ $= 726{\cdot}4$ kg.

$R/\Sigma M = 726{\cdot}4/32229 = 0{\cdot}0225 = 2{\cdot}25$ per cent.

Average maximum bolt stress = 1926·4 kg/cm².

Proportionality limit for the bronze considered = 6398 kg/cm².

The safety factor is, therefore, 3·32.

The practical conclusion is, therefore, that by using bronze bolts it is possible to reduce R from 9617 to 726·4 kg and also to increase the safety factor considerably. The type of bronze chosen has (1) a high thermal expansion coefficient which even slightly exceeds that of copper; (2) a proportionality limit equivalent to that of standard grade steel; and (3) a very low modulus of elasticity. These particular qualities can thus be utilised to achieve extensive compensation of the additional stresses due to the axial expansion of the commutator.

TESTS OF MICA PRODUCTS

The mica materials used in practice are not homogeneous but always contain a bond substance which has an elastic limit well below that of pure mica. The stress/strain diagram is, therefore, a curve of the type shown in Fig. 8. The lower part of the curves are determined mainly by the compressibility of the bond substance, and the proportionality limit of the bond substance is at the points of inflexion. Thus, strictly speaking, micanite does not follow Hooke's law. However, the inner flank pressure p_i (when the taper angle is smaller than the pitch angle) will in any case be well above this elastic limit of the bond substance, although the outer flank pressure p_e may be below this point. This will have the effect that the flank pressure actually occurring in the vicinity of the running surface of the hot commutator will be somewhat lower than the calculated pressure. The deviation from Hooke's law will not, however, be of practical importance for any of the other relationships, since the pressures considered in these cases are well above the point of inflexion. Nevertheless, it is possible that the irregularity of the elastic behaviour of mica products may be considerable, and one of the objects of the present work has been to show that a sound commutator construction depends on knowledge of the engineering properties of pure mica and mica products.

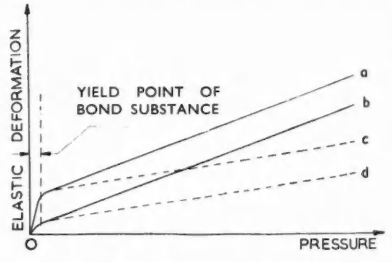


Fig. 8. **Elastic deformation of various types of micanite as a function of the compressive stress and the amount of binding medium used.**

(a) Phlogopite with high bond substance content.
(b) „ „ low „ „ „
(c) Muscovite „ high „ „ „
(d) „ „ low „ „ „

The lack of accurate data on the moduli of elasticity of the most important types of natural mica is surprising. In "Mechanical Engineering Handbook," by L. S. Marks, the values given for E_m are between 25 and 30×10^6 psi ($1{\cdot}76$–$2{\cdot}11 \times 10^6$ kg/cm²). These values, however, seem far too high for a non-metallic material and would require further confirmation. It is difficult to find an explanation for the lack of data on these constants, apart from the fact that the importance of the mechanical properties of mica has not previously been fully appreciated, and is it to be hoped that the electrical industry and the manufacturers of mica products will be able to collect sufficient test data regarding these materials in order to facilitate the manufacture of improved commutators giving satisfactory service over long periods.

PRODUCT DESIGN AND DEVELOPMENT

Present-Day Car Design Trends

AERODYNAMIC STREAMLINING VERSUS STYLING

By TIBOR HAAS, Dipl. Ing., A.M.I.Mech.E., A.F.R.Ae.S.

Appearance and engineering progress are not divorced from each other in car design, yet misconceptions as to what is essentially an engineering problem and what is the artistic interpretation of form and balance are still prevalent. The purpose of this paper, the first instalment of which was published last month, is to trace some of the many and varied engineering aspects of car design as well as their influence on the appearance of the present-day car.

The concept of aerodynamic improvement of the body involves not only air drag but also cooling, ventilation and air noise, that is to say, general passenger comfort. There are a number of problems brought into the foreground as a consequence of aerodynamic improvement, and they are awaiting realisation in conjunction with a better understanding of the established aerodynamic principles involved. Thus, a simultaneous solution of the outstanding problems will not only reduce air resistance but will form the next step in technical perfection.

Air drag, for instance, has an indirect influence on top gear acceleration, and it has been said that a truly low-drag car cannot usefully be employed without some new form of transmission system. The problem is that, with present engine power output characteristics, the increase in road speed brings the engine above its safe rpm limit. Automatic gear changing may be one answer to this problem, but perhaps not the right answer for the cheaper car. Not only the transmission system but also the engine is to be adapted to the road-load requirements of the aerodynamically streamlined car in order to obtain real improvement in fuel consumption[7]*.

To derive further benefit from aerodynamic considerations and testing, engine cooling problems have also to be considered[14]. The power required for cooling has not hitherto been assessed separately, although it can amount to 20 per cent of the engine power. The reason for not generally investigating this power consumption lies in the fact that it forms part of the power required to overcome air resistance, and is thus contained in the latter. The resistance encountered in cooling the engine, that is, the internal drag that must be overcome by the air passing through the cooler and cooling system, amounts to about 10 per cent of the total air resistance with the more conventional cars, and to a proportion up to about 25 per cent with the streamlined cars. With aerodynamic improvement of the body, therefore, special care is necessary in designing the cooling system.

As no such considerations are made in model tests, the drag values obtained do err on the low side. It follows that cooling ducts should have low air resistance, but the location of the cooling air outlet is more important than the duct design. For this reason, it is necessary to know the pressure distribution around the car body. As an example, Fig. 11 shows the pressure distribution over the German Kamm car[14]. The cooling air exit on this car was located just below the windscreen, where the static gauge pressure was of the magnitude of $0{\cdot}55\rho\frac{1}{2}v^2$ (Fig. 11). The available pressure drop through the cooler was, therefore, $0{\cdot}45\ \rho\ \frac{1}{2}v^2$. It was shown that a better cooling air exit was available below the car at points of almost undisturbed air pressure.

The usefulness of such diagrams as Fig. 11 for the study of the problem of interior ventilation of the car is obvious; also the reduction in the noise resulting from uncontrolled local turbulences is made possible by studies of this nature.

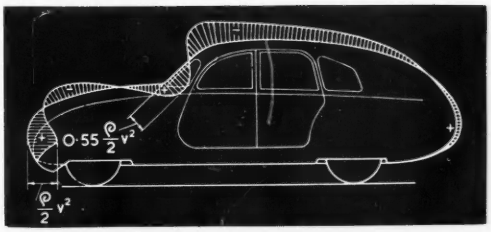


Fig. 11. **Pressure distribution over the longitudinal centre section of the Kamm car.**
+ denotes pressure. — denotes suction.

Further progress seems to lie in the direction of the application of light alloys to body construction. Production considerations would require still more rounded shapes when using aluminium alloys[3]*. The more rounded contours of light alloy panelling are favourable from the point of view of low-drag body shapes. The lower weight obtainable would enable power units of lower output to be used and, due to the lower inertia, would reduce the crash energy. Low weight is also favourable for acceleration, braking and climbing performance; also the rolling resistance is reduced. As weight would be saved rather in the upper part of the car, the centre of gravity of the car tends to move downwards, which is favourable for road holding. The real advantages of low-weight metal construction show up fully when combined with aerodynamic streamlining[15].

The Bristol car shown in Fig. 6, which has a steel tubular structure, is aluminium-panelled. The French Baby-Gregoire as well as the Hotchkiss-Gregoire type R have a bodywork composed of Alpax castings and light alloy panels[16].

During the normal running of the car, speeds fluctuate from zero to maximum. As mentioned before, in the lower speed region the rolling resistance predominates over drag; the better the streamlining, the greater is the speed range in which air drag is kept low compared with rolling resistance. Therefore, light-weight construction, which reduces rolling resistance, combined with streamlining, caters for power and fuel saving in both the lower and upper speed ranges.

Another instance may be mentioned here which shows that improvements in one direction raise problems which must be solved in order not to annul the particular improvements made. We are referring here to the springing as a new problem raised due to light-weight construction. The influence of the passenger weight, especially with the smaller car, may be considerable in light-weight construction, so that the new

* For References (1) to (13) see August issue, p. 290.

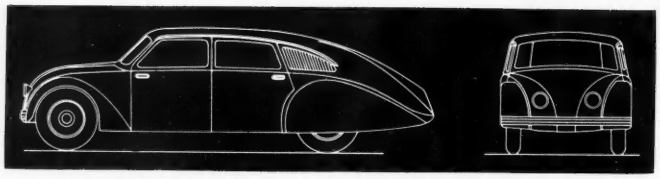


Fig. 12. **The Tatra 77 car.**

problem could be formulated as a need for adjustable springing.

Perhaps enough has been said about the various lines of attack that require development and hold out promise for a more economical car of the future. Scientific knowledge and technical development work are, however, only part of the picture. We all want to see beauty, comfort and ease of handling and maintenance in our cars. Here is a wide field open for the designers concerned; but it is also the car-buying public who will have to interest themselves in the problems likely to shape the future car, if we wish to evolve more rational designs. Aerodynamic streamlining offers a great opportunity to artists of vision. They would not have to delve too deeply into aerodynamics for inspiration of the right type. In my submission it is the aerodynamic aspect of car body design that enables the designer to evolve forms that are theoretically correct. A yardstick is afforded which removes this problem from the realm of aesthetics, if not wholly, at least to an extent sufficient for measurable progress to be made.

If the true is separated from the false, I think one can arrive at design conceptions where changes in appearance will be conditioned by evolutionary practices and not by fanciful ideas of fashion that disappear in a year or two and make the car almost obsolete when put on the market.

Fig. 13. **The Tatra 87 car.**

Fig. 14. **The Tatra 97 car.**

It may be of interest to look into a car design in which such rational developments can be traced back for several years and which are still valid in the present models.

Fig. 12 shows the Tatra 77 introduced in 1935, with its air-cooled 8-cylinder Vee engine at the rear, and Fig. 13 its later development, the Tatra 87. The

Fig. 15. **The Tatra T.600 (Tatraplan) car, featuring rear engine and aerodynamic streamlining** (Front view).

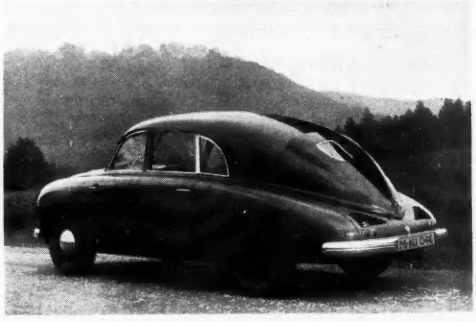


Fig. 16. **The Tatra T.600 car** (Rear view).

flat four Tatra 97 shown in Fig. 14 has its latest counterpart in the Tatra 600 (known as Tatraplan) shown in Figs. 15 and 16. The engine of the Tatraplan is shown in Fig. 17 seen from the rear. In this series of Tatra cars, we see a development over 15 years consistently adhering to the basic principles of the first model. In the Tatraplan, we have a correctly streamlined modern car of low drag (see Table I, page 287) and low power consumption. This can be seen from Fig. 18 which, in the light of the foregoing discussions, affords an interesting comparison with the curves of Fig. 3.

To illustrate contemporary car design we could show a number of the latest British cars, but these, we think, are well known to our readers, so that we choose our examples from a number of other nations.

Fig. 19 shows the Fiat 1100/S which, although not one of the latest cars, still aesthetically belongs among the best in the saloon car class.

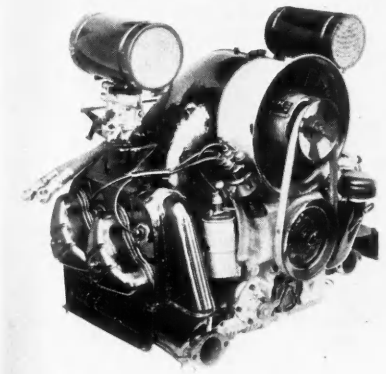


Fig. 17. **The Tatra T.600 (Tatraplan) engine seen from the rear.**

of the frontal treatment indicate that the " stylist " has not withstood the temptation of adding some meaningless decoration to the " Hansa."

The three last-named cars, as most of the British makes, have a considerably shorter wheel base and smaller frontal area than the standard American car.

Admittedly, aerodynamic forms are not readily adaptable to very small four-seater cars. However, once the aerodynamic idiom for large and medium-sized cars has found general acceptance, the small cars, no doubt, will follow suit. To achieve this, departures from orthodox drives will be necessary.

For the existing low-powered small cars there is no British counterpart. The French Dyna-Panhard 610 c.c., with front-wheel drive (Fig. 22) and the rear-engined Renault 760 c.c. (Fig. 23) belong to this class, among many other Continental makes.

For the two conceptions of drive incorporated in these cars, Britain has no answer. Experience is needed in these for any nation wishing to pioneer car design. We shall need this experience even when new forms of power become available, which, fortunately, are pioneered by Britain.

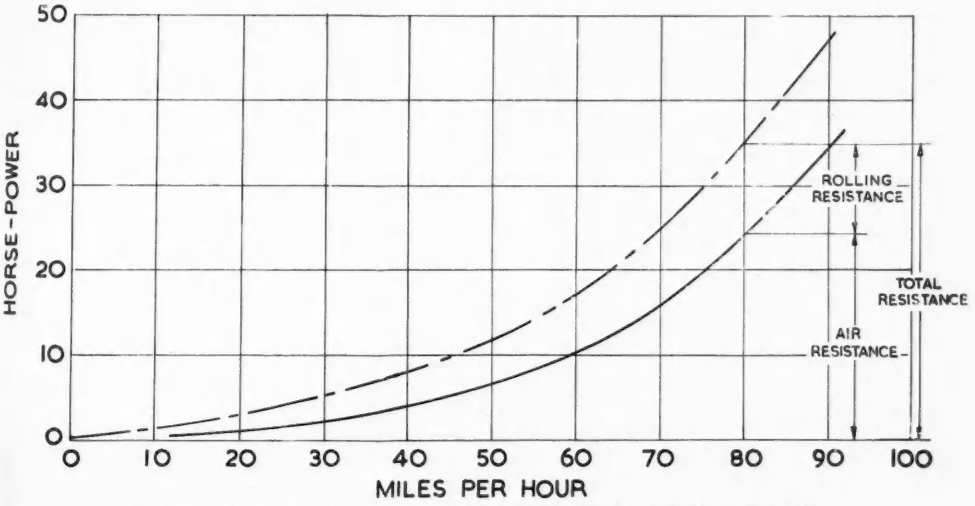


Fig. 18. **Diagram showing power required at various speeds for the Tatraplan T.600.**

Fig. 20 shows the Russian GAZ-M. 20, known as the Pobieda or " Victory " car[8], the drag coefficient of which is given in Table I. Technically speaking, this car as well as the Fiat 1100/S is as international as the German Borgward " Hansa 1500 " (Fig. 21); both have almost all the features which some of the traditionalists mistakenly call " American." Some aspects

Tradition should certainly not be belittled. We do not wish to scrap what older generations have done for us and start from scratch. Neither must we have prejudices which hide behind the cloak of tradition. Some of the first horseless carriages had whip sockets on the dashboard (a whip was not carried, as it was admitted that the "horse" could not be influenced by it).

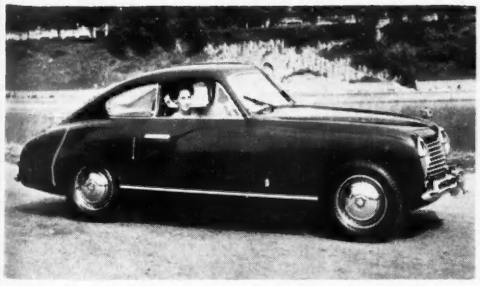


Fig. 19. **The Fiat 1100/S. Body by Pinin Farina.**

Fig. 20. **GAZ-M.20 Pobieda car.**

Fig. 21. **The Borgward "Hansa 1500," 4-cylinder engine**

Fig. 22. **The Dyna-Panhard 610 c.c.**

Fig. 23. **The Renault 760 c.c.**

Are we not still, to a great extent, affected by tradition? Our designers should not fear that the public is necessarily averse to rapid changes; instead, they should try to prepare the public to appreciate the reasons for such changes. That way lies progress.

The author's thanks are due to all those firms and individuals whose help in providing illustrations and data is herewith acknowledged.

REFERENCES.

(14) ENGINE COOLING PROBLEMS ARISING IN MOTORCAR DESIGN, by Dr. Ing. B. Eckert. *The Engineers' Digest*, Vol. 4, 1943, pp. 185-188 and 210-215. (From the German original paper in *ATZ*, Nos. 9 and 10, 1942).

(15) LEICHTBAU BEI STRÖMUNGSGÜNSTIGEN KRAFTWAGEN, by Prof. Emil Everling. *V.D.I. Zeitschrift*, Vol. 91, No. 10, May, 1949, pp. 247-251.

(16) LA GRÉGOIRE "R," by J.-A. Grégoire. From *Revue de l'Aluminium*, Vol. 24, No. 137, October, 1947, pp. 293-302.

AEROSOL INDICATOR

(*Concluded from page* 320)

weaker light beams. To use the apparatus in this manner, while going around the premises to be investigated, one can first make a rapid general exploration in order to determine the dust distribution in the premises. Observation of the variation in the dust concentration is easy, and the dangerous areas can be located and then subjected to a more detailed study.

By pressing the control knob down to the bottom position, the air circulation is stopped and the number of particles in the field of vision can be counted or estimated. The particles never remain absolutely stationary in the air chamber, owing to the air currents which are always present in the apparatus. With small numbers of particles, the counting is rapidly carried out. For larger numbers of particles, an estimate of the number is sufficient. Increased accuracy is obtained by making a number of observations and taking their mean value. This gives greater accuracy and also makes it possible to register very low dust concentrations with averages of less than one particle occurring in the field of vision. If the microscope is held vertically, one can see the Brownian motion of the particles due to intermolecular collisions.

In certain cases there may occur disturbances which are due to the fact that the air at the place under investigation is mixed with particles which are not of the basic substance being studied. For instance, tobacco smoke or water vapour may cause disturbances. In many cases, the disturbance can, however, be eliminated by a separate determination of the individual types of particles in the aspirated air and a percentage determination of their relative proportions. Under conditions of high relative humidity, the case may occur where particles smaller than the normally visible limit may become condensation nuclei for water droplets. This can be avoided or at least reduced by warming up the apparatus before taking observations, so that its temperature will be above ambient temperature.

For large-scale or more comprehensive investigations it is always useful to subject some of the samples tested with the Aerosol Indicator to absolute measurements according to standard methods, in order to determine the number, size, shape and chemical composition of the dust particles. Such measurements, however, always require a considerable amount of additional work. An important advantage of the new apparatus described above is that it is not hampered by the complications of other types of measuring equipment and, therefore, gives the possibility of obtaining a more effective and more rapid mapping of the really dangerous zones in addition to permitting a more rapid checking of the effectiveness of ventilating systems than is achievable with other equipment.

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

AIRCRAFT ENGINEERING

Development of High-Speed Water-Based Aircraft

By E. G. STOUT. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 17, No. 8, August, 1950, pp. 457-480, 24 illustrations.)

OUTSTANDING progress has been made in recent years in the field of seaplane hydrodynamics which has done much to bring the faltering seaplane up to modern standards of aerodynamic performance and design efficiency. In fact, extensive research programmes, utilizing the dynamically similar model technique, promise to place consideration of water-based aircraft high on the programme of current defence planning.

This paper outlines the salient features involved in the development of the dynamic model and associated research techniques into a practical, accurate research tool for designing water-based aircraft that demand little, if any, compromise with contemporary aerodynamic design. New seaplane design criteria are discussed, and their application to high-performance water-based aircraft is analysed. With the high-speed propeller-driven seaplane now an actuality, attention is drawn to the solution of the supersonic water-based problem.

It is concluded that adequate design criteria and technological experience are available to meet satisfactorily or to exceed any aircraft requirement with a suitable water-based configuration.

ELECTRONICS

Studies of Thyratron Behaviour

By L. MALTER and E. O. JOHNSON. (From *RCA Review, U.S.A.*, Vol. 11, No. 2, June, 1950, pp. 165-189, 27 illustrations.)

PART 1 of this paper explains the role of grid resistance in recovery of grid control following the interruption of a discharge. A picture is presented of the processes which occur during the post-discharge (or after-glow) period and of the manner in which recovery of grid control is effected.

It is known that the recovery time of thyratrons increases with increasing value of grid resistance. It is shown that a common conception that this is due to decreased rate of de-ionization with increasing grid resistance is erroneous. On the contrary, the positive ion current to the grid (and consequently, de-ionization) is shown to be essentially independent of grid resistance and voltage. The increase of recovery time, in the presence of grid resistance, is due to a delayed return of the grid voltage to its bias value. Recovery time is demonstrated to depend upon the value of the instantaneous grid potential and to no appreciable extent upon the course of the grid potential during the period following the interruption of the discharge, unless an abrupt change in grid potential occurs shortly before recovery.

In Part II of this article it is shown that the recovery time of thyratrons is dependent upon the course of the grid potential during the period following the interruption of a discharge, only if the grid potential experiences a sudden change during some time interval just preceding the test for recapture of grid control. This test may be the re-application of anode voltage. A picture is presented, according to which any sudden change of grid potential sets up an unstable charge distribution in the plasma and sheaths within the tube. This unstable configuration goes over into a quasi-stationary one at a time determined by diffusion considerations. Evidence for this picture is presented.

IRON AND STEEL

Investigations into the Impact Strength of Iron and Steel

By J. D. FAST. (From *Philips Technical Review, Holland*, Vol. 11, No. 10, April, 1950, pp. 303-310, 9 illustrations.)

THE results are discussed of experiments carried out to investigate the notched-bar impact strength of pure iron and of iron to which impurities were purposely added. This is preceded by a review of the simplest concepts that can be formed according to known theories about the relation between the state of stress in a loaded metal and the possible occurrence of plastic deformation and/or rupture. According to this simplified picture, plastic deformation of the material takes place when, under increasing load, the shear strength of the metal is exceeded before the cleavage strength; in the opposite case, the metal shows a brittle fracture. In the impact test, the state of stress during the loading is such that there is a greater chance of brittle fracture than under the conditions of the ordinary tensile test.

It appears that oxygen considerably reduces the impact value of iron at 20°C, but traces of carbon may greatly diminish this harmful effect. As a result of the marked increase of shear strength with falling temperature (assuming the cleavage strength to remain constant), the impact value of pure iron when the temperature drops to around 0°C shows the same transition from high to low values as is already known in the case of commercial mild steel. Due to an adiabatic temperature rise taking place in the deformation zone during the bending of the test bar, this transition extends over a shorter temperature range than is the case with tensile or bending tests carried out more slowly. When oxygen is present in the iron, the transition range is shifted to higher temperatures; oxygen reduces the cleavage strength of iron. Above the transition range, carbon causes the impact-value curve to rise gradually with increasing temperature, whilst nitrogen gives rise to a flat minimum in the curve at temperatures of about 400°C. Such a minimum is shown by the impact-value curve of mild steel, also when it does not contain any nitrogen. No really satisfactory explanation for this phenomenon can yet be given.

METALLURGICAL ENGINEERING

Hot Hardness of Hard-Facing Alloys

By H. S. AVERY. (From *The Welding Journal, U.S.A.*, Vol. 29, No. 7, July, 1950, pp. 552-578, 30 illustrations.)

HOT hardness, which is of interest chiefly because of the implied hot wear resistance, has been surveyed at 600, 800, 1000 and 1200°F for a number of hard-facing alloys, using a Rockwell diamond indentor technique. Some indication of creep resistance, which becomes important as a variable at the higher tempera-

ture, is obtained by incorporating a time factor in the test.

Arc welds, gas welds and castings of wear-resistant alloys are included in the survey, which includes most of the types in the current A.W.S. classification of hard-surfacing alloys. For a few materials creep and stress-rupture data are correlated with hot hardness.

Tempering response, secondary hardening, intrinsic solid solution hot strength and the contribution of hard compounds (chiefly carbides) all influence hot hardness. Low-alloy steels with little resistance to tempering lose hardness rapidly. Alloys such as chromium, tungsten and molybdenum, which cause marked secondary hardening, contribute to good hardness retention up to and above 1000° F. At 1200° F, solid solution hot strength and primary carbides appear to be of major importance. The Cr-Co-W alloys generally exceed other alloys in hardness at 1200° F, but their properties vary widely with carbon content. Since toughness, as indicated by compression tests, varies inversely with carbon content, a compromise between hardness and toughness is required.

The Influence of Grain-Boundary Segregations on the Corrosion Resistance of Chrome-Nickel Steels

By L. PIATTI. (From *Technische Rundschau Sulzer, Switzerland*, No. 1, 1950, pp. 27-31, 8 illustrations.)

A CHEMICAL mixer for corrosive substances with solid particles in suspension was built in 1945. The mixing vessel, designed for an internal pressure of 570 psi, had a cylindrical shape with a spherical dished lower end, and was welded from pre-formed austenitic 18-8 chrome-nickel steel plates. After 3½ years of service, the spherical end plate and one cylindrical wall plate were found to be badly corroded locally, whilst all the other plates, though exposed to the same service conditions and made from apparently identical material, showed hardly any traces of corrosive attack. The intensity of local corrosion was obviously due to erosion by the mixing action and the abrasive effect of solid particles which constantly removed the protective oxide film formed by initial corrosion of this material. Once started, the corrosive attack could thus progress without hindrance. However, the fact that only two plates were badly corroded, whilst the others, and even the welds, remained intact, shows that other, distinguishing, factors must have been the cause of the initial corrosion.

According to the chemical as well as the spectrographic analysis, the compositions of the corroded and uncorroded plates were identical, apart from deviations within the range of measuring errors (18 Cr, 8 Ni, 0·55 Mn, 0·43 Si, 0·05 C). The weld material contained 18·7 Cr, 9·25 Ni, 0·97 Mn. The metallographic structures of plate material and weld transition zones again provided no clue for the selective corrosion attack. The X-ray diffraction pattern showed a well crystallized coarse austenitic grain throughout without any traces of cold work. The back-reflection pattern, however, taken from a specimen at rest on a film rotated about the X-ray beam axis, indicated a slight difference in the diameters of corresponding interference rings. Evaluation gave a slightly smaller lattice constant for the corroded plate (3·582 Å) than for the uncorroded plate (3·584 Å). It follows that in spite of identical analyses, the single austenite crystals of the corroded plate had a slightly lower chromium content because some chromium had been segregated at the grain boundaries in the form of carbide. The difference must have been less than 1 per cent.

It should be noted how small and how local a difference of composition produces striking differences in the corrosion behaviour of a material. Admittedly, the present example is exceptional, but under conditions of a similar kind, it might be well to investigate the composition of single crystals in this manner, or to arrange for special corrosion tests. The phenomenon here described might well lead to an improved knowledge concerning stress corrosion, cavitation corrosion and similar effects.

WELDING

Micro-Mechanical Test Methods Applied to Welding Tests

By N. MIRONOFF. (From *L'Ossature Métallique, Belgium*, Vol. 15, No. 6, June, 1950, pp. 293-297, 14 illustrations.)

IN the vicinity of welds, the mechanical properties of the welded materials usually change very abruptly from spot to spot. To obtain a knowledge of the localised properties, therefore, requires tests over very small areas or with very small specimens. The hardness tests fulfil these requirements, but do not give sufficient evidence for a complete analysis of the conditions. The author has, therefore, developed a micro-tester for very small test specimens, which are bent to and fro through a certain angle, the number of bending reversals to fracture serving as an indication of the ductility of the material. Careful performance and evaluation of these tests ensure that results of a quantitative, comparable nature will be obtained. Since many welds fail due to insufficient ductility of the material in or near the weld, and since this test method allows of taking local tests at very small intervals throughout the weld-affected zone, a valuable criterion and test for the study of welding effects is thus given, especially if these tests are analysed in combination with hardness tests taken on corresponding regions of the weld.

Test results are shown for a weld on Cr-steel (1 Cr, 0·25 C, 0·25 Mo, 0·5 Mn), 40 to 45 tsi U.T.S. Test specimens were taken at 5 mm (0·2 inch) intervals across the welds, and hardness (Brinell) and ductility (number of bending reversals to fracture) plotted over the distance from the centre of the weld. Although the material welds satisfactorily, the weld seam itself is hard and brittle in the as-welded state, and the affected zone next to the weld is also harder and slightly less ductile than the un-affected parent material. Annealing at 600° C reduces the hardness of the weld to a figure slightly lower than the hardness of the parent material. Nevertheless, the ductility has not yet reached the figure of the parent material, an indication that the hardness test alone cannot disclose all the essential changes in the material. It is only a combined annealing treatment at 850 and 600° C that will ensure uniform properties throughout the welded structure. The test deductions are supported by micrographs showing the relevant alterations of the metallographic structure, as well as by macrographs indicating the influence of grain size.

A MODERN AMERICAN TUBE MILL

(*Concluded from page* 304)

machines of various types, cut-off machines, hydrostatic testers, pipe-coating equipment and tables for inspection and packaging.

Processing Department

Tubing other than hot-rolled requiring further treatment, such as pickling, doping, cold-tube reducing, cold-drawing, pointing, normalizing, intermediate and final annealing, is processed in this department. The furnaces are of the continuous roller-hearth type for normalizing and bright annealing and of the convection type for imparting structure and tensile properties.

The cold-working division consists of drawbenches of 20,000 to 300,000 lb capacities and tube reducers handling tubing of 1½ to 3½ in. o.d.

NEWS OF THE MONTH

PERSONAL.

Mr. W. D. Akester has been appointed home sales director of Ransomes, Sims and Jefferies Ltd.

Mr. R. Graham Bailey, deputy chairman, The Rockware Glass Syndicate Ltd.; **Sir Patrick Hamilton, Bt.,** director, Henry Simon Ltd.; and **Mr. H. F. Spencer,** assistant managing director, Richard Thomas and Baldwins Ltd., have been elected to the Council of the British Institute of Management, 8 Hill Street, London, W.1.

J. Calvin Brown, of Los Angeles, Calif., owner of the firm bearing his name in that city, has been nominated as the 1951 president of The American Society of Mechanical Engineers. Regional vice-presidents nominated are: **Henry Reginald Kessler,** manager, Republic Flow Meters Co., New York; **Stephen Dewey Moxley,** vice president, American Cast Iron Pipe Co., Birmingham, Alabama; **Dr. John T. Rettaliata,** dean of engineering, Illinois Institute of Technology, Chicago, and **Carl J. Eckhardt,** professor of mechanical engineering and superintendent of utilities, University of Texas, Austin. Nominated as directors-at-large: **Lionel J. Cucullu,** assistant to chief engineer, New Orleans Public Service, Inc., New Orleans, La., and **Harold E. Martin,** district manager, The Babcock & Wilcox Company, New York.

Professor C. H. Bulleid, O.B.E., M.A., A.M.I.C.E., M.I.Mech.E., has been elected President of the newly formed East Midlands Metallurgical Society. **Mr. J. W. Gailer, M.Sc., F.R.I.C., A.I.M.,** has been elected honorary secretary.

Mr. H. G. Campbell has been appointed joint managing director of the Benjamin Electric Co., Ltd.

Mr. G. F. Cole, director and secretary of Clarkson (Engineers) Ltd., Nuneaton, has been appointed general manager of the Company.

Mr. R. H. Cooke has been appointed assistant manager of the X-ray department of Philips Electrical Ltd.

Air Chief Marshal Sir W. Alec Coryton, K.C.B., K.B.E., M.V.O., D.F.C., Controller of Supplies (Air), Ministry of Supply, has been appointed Chief Executive, Guided Weapons. This post has been created at the Ministry with the object of accelerating and co-ordinating all work in research, development and production of guided weapons. **Air Vice-Marshal J. N. Boothman, C.B., D.F.C., A.F.C.,** succeeds him as Controller of Supplies (Air), and will become an additional member of the Air Council and be promoted to the acting rank of Air Marshal. He is now responsible for research, design, development, production and inspection in the aircraft field.

Mr. M. F. Dowding, M.A., A.M.I.Mech.E., has been appointed engineering sales manager of the Davy and United Engineering Co., Ltd.

Mr. C. L. G. Fairfield, M.A., A.M.I.E.E., A.M.I.Mech.E., has been appointed a director of Mullard Equipment Ltd.

Mr. G. P. Goodman, M.I.E.E., has been appointed as an engineer in the traction contracts branch of the British Insulated Callender's Construction Co. Ltd.

Mr. L. L. Goodman, B.Sc.(Eng.), A.M.I.E.E., A.M.I.Mech.E. has joined the staff of the British Electrical Development Association, 2 Savoy Hill, London, W.C.2, as technical officer dealing with industrial power matters.

Brigadier W. A. Lord, M.Eng. (L'pool), A.M.I.Mech.E., has been appointed director of mechanical engineering, Middle East Land Forces, with temporary rank of Major-General.

Mr. C. R. Middleton has taken up appointment as manager of the Stanlow refinery of the Shell Petroleum Co., Ltd., at Ellesmere Port, in succession to **Mr. F. Mackley,** who has been transferred to the head office of the Company.

Mr. A. J. Romer has been elected to the Board and appointed managing director of A.E.C. Ltd., Southall, Middlesex. He will also join the Board of the A.C.V. Group, the parent company of A.E.C. Ltd.

Mr. H. J. Sims, A.F.R.Ae.S., has joined Airspeed Precision (London), Ltd., 22, Bruton Street, London, W.1, as designer and chief draughtsman.

Mr. A. C. Wildsmith, A.M.I.C.E., A.M.I.W.E., has been appointed water engineer and manager, Halifax Corporation.

BUSINESS NOTES.

The 1951 British Industries Fair will be held in London, at Earls Court and Olympia, and in Birmingham at Castle Bromwich from 30th to 11th May.

The response to application forms for space is already an all-time record and indicates that this will be the largest and most comprehensive trade fair ever organised in Britain. The organisers are arranging to extend the stand space as far as the limits of the fair buildings and the interests of the exhibitors will allow.

B.I.F.'s best year for exhibitors was 1948, when 3,430 participated. The best year for space was 1950, when there were 483,973 square feet of stands. Both these records are likely to be broken by the 1951 Fair.

A world-wide publicity campaign is being planned and will again include a special effort in North America; there is every reason to hope that the record of 19,005 overseas buyers who visited B.I.F. last year will be surpassed in 1951.

Letters will go out this month to 130,000 overseas trade buyers drawing their early attention to the exceptional double attraction of a visit to Britain for the Fair and for the Festival, whose opening ceremonies will take place while the Fair is in progress.

Engineering and hardware industries will again be accommodated in Birmingham and the lighter industries in London.

A Process Development Advisory Bureau to give free impartial advice on various phases of Industrial Finishing, has been set up by Alfred Bullows & Sons, Ltd., Walsall, under the control of Mr. A. Rice-Williams, who until recently was in charge of the Paint Experimental and Development Department of The Rover Co., Ltd., of Solihull.

Free consulting service on Industrial Finishes in general, embraces queries on Pretreatment Problems; Choice of Finish and Materials, Economics of Application, Stoving Problems, Tracing and Eradicating Finishing Troubles, etc.

The British Motor Racing Research Trust wishes to state that no proprietary parts or assemblies were involved in the mechanical failure which prevented the B.R.M. from racing in the *Daily Express* trophy race at Silverstone on August 26th last.

Sir George Godfrey & Partners Limited, of Hampton Road, Hanworth, Middlesex, have undertaken a major reorganisation in the structure of the Company, made necessary by the rapid expansion over the last few years. The expansion takes the form of three new Companies, Sir George Godfrey and Partners (Holdings) Limited, which is the financial controlling company, with two subsidiaries, Sir George Godfrey & Partners Limited, who will continue to specialise in aircraft pressurisation and air conditioning equipment, and Sir George Godfrey and Partners (Industrial) Limited, which has been formed to undertake the industrial interests of the Company.

Three new Directors have joined the Boards of the subsidiary Companies, and these are: Mr. R. W. Everall, who was previously with Blackburn and General Aircraft Company, who has been

RECLAIM MACHINE SHOP ERRORS & WORN PARTS

by the BRAILEY (Regd) PROCESS

OF HARD CHROMIUM AND HEAVY NICKEL ELECTRO-DEPOSITION

We can tackle those component difficulties in our up-to-date plant. Our 32-page booklet covers many applications of the process and will be sent on written request to responsible enquirers.

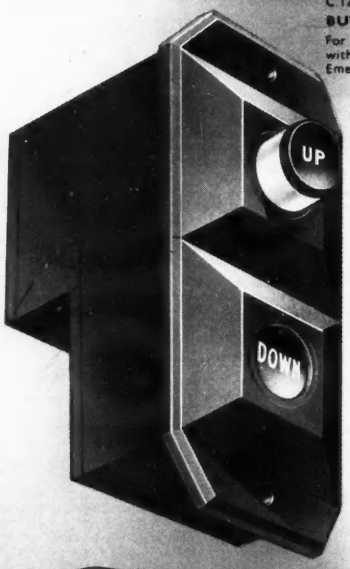
BRAILEY Electroplaters Ltd

ESTABLISHED — 1872

CHAPEL ST · SALFORD · LANCS.

B45

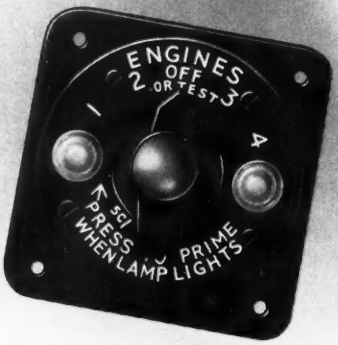
C.1212-Y Mk.5
BUTTON SWITCH
For Undercarriage Retraction with Electrical Lock and Emergency Over-ride.



DOWTY
Electrical Equipment

A selection of switches representing types fitted to the following aircraft :

Airspeed *Ambassador* • Armstrong Whitworth *A.W. 52 and Apollo*
Avro *Athena and Tudor 9* • Avro Canada *C.102 and C F.100*
Blackburn *Universal Freighter* • Bristol *Brabazon 2*
English Electric *Canberra* • Hawker *Sea Hawk*
Saunders Roe *Princess and S.R.A.1* • Short *Solent*
Vickers Armstrongs *Valetta and Varsity*
Westland *Wyvern and T.12 48 Trainer*



C.1820-Y Type
PRIMING SWITCH
for 2 or 4-engined Aircraft

C.1223-Y Type
LEVER SWITCH
for Flap, Bomb Door, Air Brake Control, etc.

C.1220-Y Type
DRUM SWITCH
for Flap, Air Brake Control, etc

DOWTY EQUIPMENT LIMITED · CHELTENHAM

appointed a Director and General Manager of the aviation interests; Mr. Fisher who has been with Sir George Godfrey and Partners Limited since 1942 as Chief Accountant and Secretary will join the Board of the Industrial Company, and Mr. N. Anderson who was Chief Engineer of Sir George Godfrey and Partners Limited has been appointed to the Board of the Aviation Company.

It will be recalled that Sir George Godfrey and Partners Limited have three flourishing subsidiary companies in Canada, South Africa and Australia respectively.

The Brush Electrical Engineering Co. Ltd., of Loughborough, has acquired a controlling interest in the Vivian Diesel Engine Works, Ltd., of Vancouver, British Columbia.

Mr. Jack Humphries has been appointed Sales Manager, American Equipment Division, of A. A. Jones & Shipman Ltd., Narborough Road South, Leicester. This appointment has been made following the conclusion of the sales and manufacturing agreements with the Micromatic Hone Corporation, Detroit, U.S.A. and also the selling agency for the complete range of machines manufactured by the Ex-Cell-O Corporation, Detroit, U.S.A. Mr. Humphries is shortly visiting America to obtain first hand information on these products and to make personal contact with these companies. He was previously on the Managerial Sales Staff with the Index Division of the B.S.A. Tool Group.

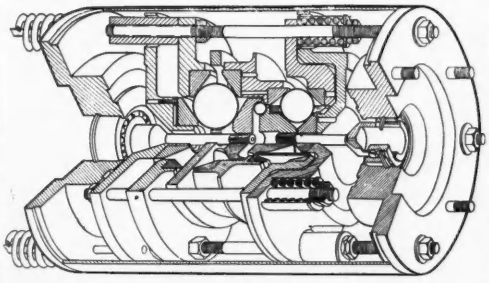
NORTHERN IRELAND AND RE-ARMAMENT WORK

Considerable interest has been aroused by the visit of Mr. McCleery, the Northern Ireland Minister of Commerce, to the Minister of Supply and the Parliamentary Secretary to the Admiralty in London. This visit was purely exploratory, the object being to put before Imperial Ministers the extent to which manufacturing capacity and labour resources of Northern Ireland might be available to contribute to the United Kingdom requirements.

NEW EQUIPMENT.

THE GERRITSEN GEAR

This gear developed by Tiltman Langley Laboratories, Ltd., is a new form of compact and easily serviced mechanical transmission. It provides an infinitely variable gear with ratios in 1/1 range or with high reductions and the gear is capable of operating at high speeds. It can be self-governing and can control output speed within ± 1 per cent. Sensitive control by manual means, thermostats, barostats or servo-mechanisms can be provided without lag or hunting.



The gear is of the mechanical friction type, and in principle consists of a number of hard steel balls rolling without slip over four coned hard steel surfaces. The balls are preloaded between the surfaces, in order to transmit power. The rolling characteristics of the balls are determined by fixing two of the surfaces relative to each other. By choosing different surfaces, different types of rolling will be obtained and, consequently different types of gear ratios will be found.

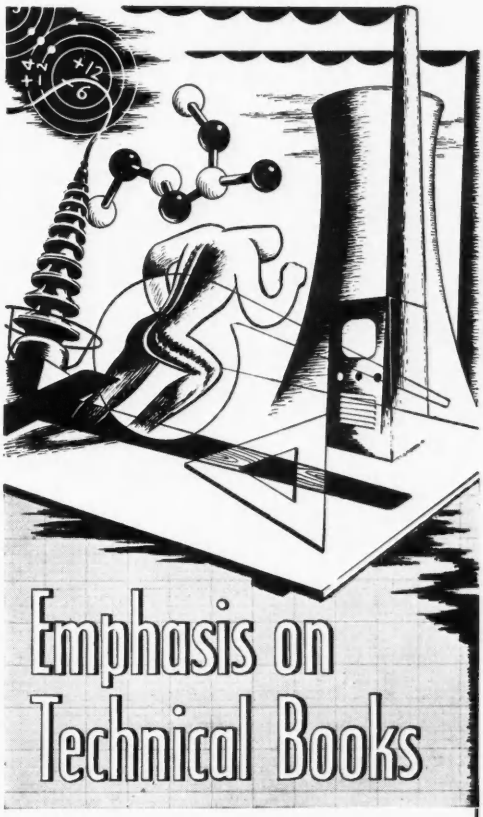
The first gear to demonstrate the self-governing principle is shown in the above illustration. Axial movement of the coned surfaces is reacted by the external governing springs which were installed in this manner only for experimental purposes.

THE BTH GAUSS METER TYPE G

New realms in the measurement and investigations of D.C. magnetic fields have been opened up by the recent introduction of the BTH Gauss Meter Type G—a new and compact device for measuring flux densities up to 25,000 gauss. The instrument enables measurements to be made in extremely small air gaps such as those encountered in instrument magnets and loudspeaker fields and it should prove of particular interest to magnet and loudspeaker manufacturers, both from the point of view of research and quality control of finished products. The Gauss Meter has, however, numerous other applications in all branches of the electrical engineering industry ranging from the indication of strength and direction of stray magnetic fields, and polarity checking, to the measurement of flux density in the air gaps of all types of D.C. machines.

Among the many attractive features of the instrument is that it incorporates a robust panel type meter giving a continuous reading of field strength—rather than a ballistic reading such as that obtained with the more conventional types of apparatus using galvanometers.

The instrument employs the "HALL EFFECT" in germanium and consists of a control unit measuring approximately 6" × 6" × 6"



Executives,
technical training officers,
and works librarians
who are constantly seeking the newest technical publications will find a quick and competent service at any branch of W. H. Smith & Son. Bookstalls can supply your requirements just as easily as the W.H.S. shops. Each is in daily contact with Head Office in London and your orders, either for single copies or complete works libraries, will be fulfilled within the shortest possible time.

W. H. SMITH & SON
for service
BRANCHES THROUGHOUT THE COUNTRY

HIGH PRODUCTION SCREWING TO PASS INSPECTION EVERY TIME.

ALL TUBES UP TO 18" DIA.

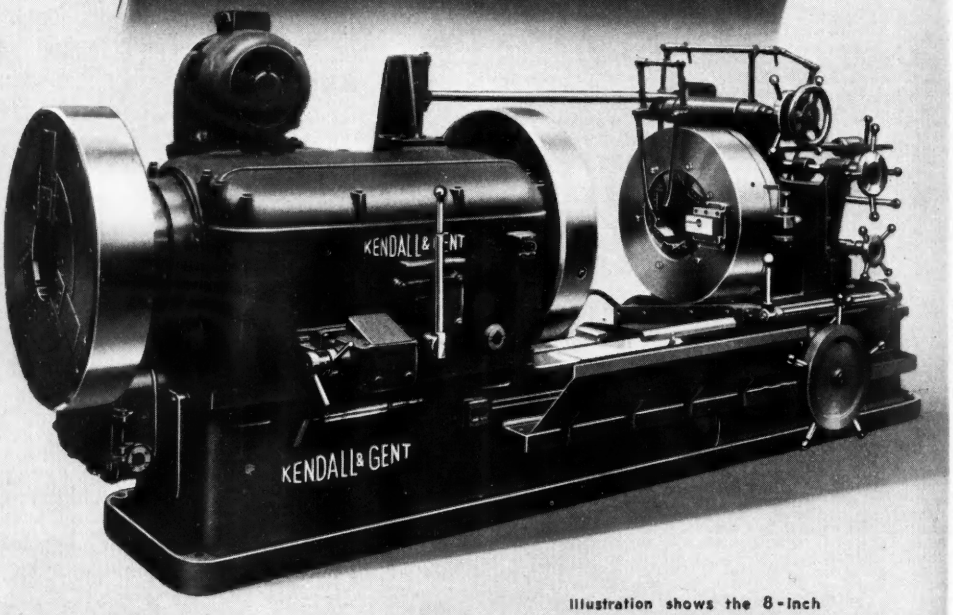


Illustration shows the 8-inch Tube Screwing & Cutting-Off Machine which is typical of our range covering all sizes up to 18-inch

KENDALL & GENT LTD VICTORIA WORKS · GORTON · MANCHESTER

PHONE: EAST 1035

K 173A

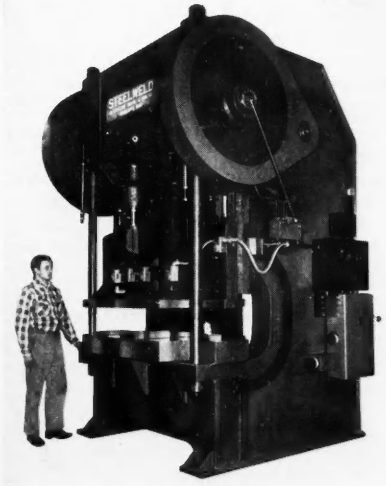
and a probe for placing in the magnetic field under test. The control unit incorporates a micro-ammeter, calibration and zero adjusting rheostats, and a 4·5-volt battery, making the equipment independent of all external power supplies. A five-way rotary switch on the front panel has "Off" and "Calibrate" positions and is used for selecting a suitable meter range of 5,000, 10,000, or 25,000 gauss.

The probe (a sheath which houses the germanium "Hall" plate) measures only 0·140" × 0·035" and is 1¼" long as standard. This sheath is usually of non-magnetic metal, but can be of a non-magnetic material and either type can be made longer than 1¼" if necessary, for special applications.

Further particulars of this device and its possible applications and methods of use, can be obtained from the BTH Research Laboratory, Rugby.

SPECIAL STEELWELD BENDING PRESS

The illustration shows a special steelweld bending press of 300-ton capacity for blanking out clutch rings clutch gear teeth, and for special flat blanking operations. The press is designed for operation by two men. It has air-electric clutch control with a 4-position selector switch situated on the right hand housing. The operators have simply to set the selector switch to any one of the four positions which are desired: "long" stroke, "short" stroke, "continuous" stroke or "inching" stroke and depress the starting buttons.



Two sets of control buttons are provided; one set on the front of the machine and the second set at the rear of the machine. The buttons are so arranged that the operators have to depress both sets of buttons to put the machine in motion, yet either operator may stop the machine at any time if he so desires.

The speed of the machine is 25 strokes per minute. The shut height is 14 in. and the throat depth is 18 in. The bed is 3 ft. front to back by 4 ft. between tie-rods. The tie-rods, which are supplied for additional regidity can be lifted up, out of the way, so that the entire length of bed can be utilized. Longer guides and larger bearing area are provided for punching service. The machine is a product of The Cleveland Crane and Engineering Company of Wickliffe, Ohio.

BRIGHT ANNEALING FURNACE INSTALLATION

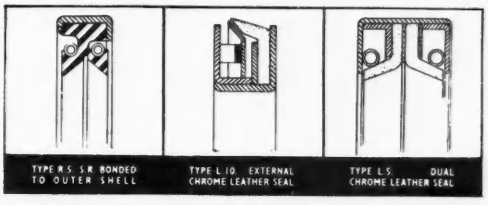
A very efficient furnace installation for the bright annealing of wire has been installed by The General Electric Co. Ltd. in the Ambergate works of Richard Johnson and Nephew Ltd. This installation, which is the second of its kind supplied to the Company consists of three vertical cylindrical furnaces, each rated at 90 kW and eighteen annealing containers 68 in. deep and 33 in. in diameter.

Twelve of the containers are normally housed in simple brick-lined cooling pits and provision is made for storing six in thermally insulated pits which form recuperators. When a continuous cycle of production is in operation, newly charged annealing containers are placed in the recuperators alongside hot containers recently removed from the furnaces. By this means a new charge can be pre-heated to about 200° C with a resultant saving of power. Moreover, recuperation is of substantial value where the new charge carries residual amounts of lubricant applied during rolling processes, because the slow initial rate of heating enables these lubricants to be driven off without "cracking" taking place and considerably improves the final finish of the wire.

The shell of each furnace consists of a welded mild steel cylinder with a flat bottom plate. The top plate has a cylindrical pro-

Our technical representatives will gladly advise you on the varying types of the Weston Seals. These include our Gitseals and Weston Oil Retainers fitted with best quality chrome leather inserts, also the Weston Synthetic Rubber Oilseals all precision made to give the lightest possible contact consistent with efficient sealing.

WESTON
OIL SEALS

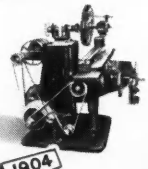


CHARLES WESTON & CO. LTD., IRWELL BANK WORKS, DOUGLAS GREEN, PENDLETON, SALFORD, 6.
PHONE: PENDLETON 2857-8-9. BIRMINGHAM, MIDLAND 6952. LONDON, HOLBORN 0414
Smee's W50

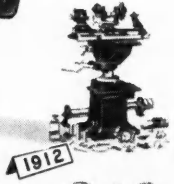
WHEN GRANDPA WAS INDENTURED

1889

1897



1904



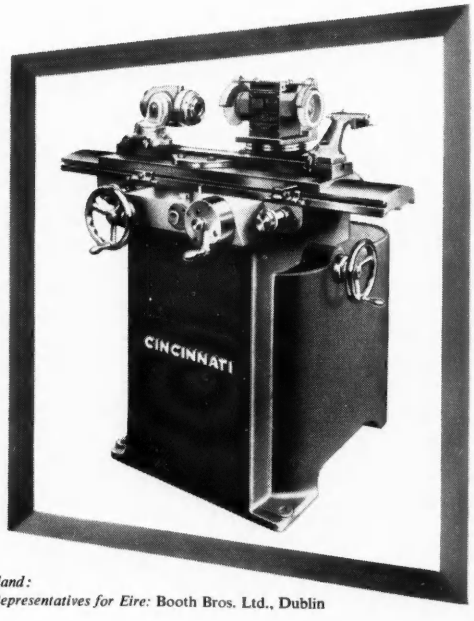
1912

1929

There are old engineers alive to-day (although, we hope, in happy retirement) who were apprentices sixty years ago, and who can probably recall the first type of cutter grinder made by Cincinnati in 1889.

From that early date Cutter Grinder development has had to keep pace with every extension of machine tool practice which, as all know, never stands still for long. Closer and closer limits ; the introduction of new methods and materials ; the ever-widening scope of machine tool work has called for refinements and even revolutions in Cutter and Tool Grinding, so that the cutter grinder of to-day bears little resemblance except in fundamental operation, to the original model produced in 1889.

Because of their intimate association with machine tool development, Cincinnati have a unique record in cutter grinder design, too, and the modern Cincinnati Cutter and Tool Grinder brings to the hand of the skilled operator (who is more than ever a necessity for good work), a tool of high precision and utmost reliability.



CINCINNATI
CUTTER GRINDER

CINCINNATI MILLING MACHINES LTD., TYBURN, BIRMINGHAM 24. *Sales Representatives for Gt. Britain and N. Ireland:* Charles Churchill & Co. Ltd., Coventry Road, Birmingham 25. *Sales Representatives for Eire:* Booth Bros. Ltd., Dublin

jection down into the furnace chamber to protect the refractory bricks at the mouth and also to guide the charge container so that it cannot come into contact with the heating elements and damage them.

Special attention has been given in the design to the matter of temperature uniformity in the charge and to reducing the overall heating time. The side walls of the furnace are made of 3 in. of refractory material backed by 12 in. of insulation. The three-phase heating elements are each in two sections and alternate coils are automatically switched off 10° C before the desired temperature is reached. This slows down the rate of heating prior to final operation of the automatic temperature control gear and so prevents any overshoot. A part of the heating elements is arranged in the bottom of the furnace to provide heat for the densest part of the charge.

The charge is carried on a base casting which is suspended from an insulated pot head by means of three heat and creep-resisting bars. This contruction allows the use of a light-weight pot envelope, which allows the rapid transfer of heat from the furnace to the pot and thence to the charge.

The pot is closed by clamping the pot head on to a rubber ring fitted into the top of the pot. This ensures a gas-tight seal and the rubber ring is cooled by circulating water through a channel round the top of the pot. An average weight of 20/25 cwt of wire is carried in each pot.

An atmosphere of partially-burnt town gas supplied by a G.E.C. gas burner, surrounds the charge. The gas is cooled and scrubbed and has its dew point reduced to about minus 4° C by means of a separate silica gel drying unit before it comes in contact with the charges in the pots. This unit is of a duplex character so that each absorber of 12-hour capacity can be re-activated in turn whilst its companion is in use. The furnaces operate at temperatures up to 750° C and the power consumption, which varies with the time cycle and maximum temperature, is of the order of 200-220 units per nett ton of charge.

SLAG FUMING PLANTS FOR SALVAGING CRITICAL METAL.

While the demand for non-ferrous metals far exceeds supply and the present military situation emphasises the need to conserve all available material, significant beginnings have been made in the U.S.A. toward the recovery of vast quantities of zinc, lead and other critical metals through a process known in the smelting industry as "slag fuming."

Slag fuming is a highly efficient process for recovering metals from slag dump residue which had been discarded after ordinary smelting operations as being economically useless. During and since the last war, three installations of slag fuming equipment have been made in North America, according to D. V. Sherban, of The Babcock & Wilcox Company, which has worked closely with the smelting industry in developing and manufacturing the equipment for this process.

The first installation of B & W designed fuming equipment was made in the Kellog, Idaho, plant of The Bunker Hill and Sullivan Mining Company in 1943. This operation recovers 40 to 45 tons of zinc, in addition to a smaller amount of lead from approximately 400 tons of slag daily. The second installation of this equipment was made at the El Paso, Texas, plant of The American Smelting and Refining Company, which went into service two years ago.

The latest installation, which is now being erected was made at Flin Flon, Manitoba, 600 miles above Winnipeg in the Canadian Northwest and near the Arctic Circle, for the Hudson Bay Mining and Smelting Company. At this smelter there is an 800,000-ton accumulation of residue containing about 26 per cent zinc alone, it is estimated.

Sherban describes the fuming operation as a process in which zinc or lead, in the form of vapour or fumes, is boiled or "fumed" up from the surface of a furnace-load of molten slag. The vapour is converted into a metallic oxide which is cooled and collected as a solid mass, or as a powder known as "fume" for further processing into finished metal.

LARGE-SCALE PRODUCTION OF GAS TURBINE POWER PLANTS IN THE UNITED STATES.

Large-scale production of gas turbines for land, railroad, and marine use, has been started by the General Electric Company in Schenectady, N.Y.

Glenn B. Warren, manager of the company's Turbine Divisions, announced that "accelerated production" has begun on the first few of more than 20 gas turbines scheduled to be built within the next two years for power generation and for gas pipe-line pumping stations.

Gas turbines now scheduled for production will be in three basic models :

A 3500-kW (4800-hp) simple-cycle type, similar to three units now operating—one for a Southwestern utility company, one for a New England power company, and the other in a gas turbine-electric locomotive ;

A 5000-kW two-shaft compound-cycle type for power generation use ;

And a newly designed 5000-hp two-shaft mechanical-drive type for gas pipeline pumping and other applications. This will be a more efficient machine than the 3500-kW simple-cycle machine. A unit of this type with a 4000-kW generator has been sold to an electric utility for power generation.

Other sizes and types will be put into production as the gas turbine programme develops, Warren said.

He emphasized that "future applications for the gas turbine are many and varied." Because large quantities of water for heat transfer or cooling purposes are not required, its use appears favourable in regions where water is scarce or costly.

Warren pointed out that there is a possible use for gas turbines on large electric utility systems having outlying load centres. In this case a small 5000-15,000-kW gas turbine plant tied in with existing transmission lines could serve as a voltage stabilizer at a newly growing load centre and thus relieve the major system of peak load demand and permit existing transmission facilities to continue to serve without enlargement.

He pointed out that a gas turbine can be started and placed under load in a short time. "This operating feature, as well as the possibility of remote control, suggests its use also for emergency and peak load service."

Because of its compactness and quick-starting ability, the simple-cycle unit is well suited for locomotive and marine use as well as for mounting on a railway car or motor truck for portable emergency power generation use.

The availability of gas or oil for fuel, the low water requirements and the compactness of the gas turbine make it ideally suited for gas pipeline pumping. The possibility of waste-heat recovery from the exhaust of the simple-cycle unit also suggests its use in industrial plants where heat or process steam is required.

Three G.E.-built gas turbine power plants are now in operation. One, a 4800-hp simple-cycle unit burning bunker "C" oil, is installed in an Alco-GE locomotive. Although in the developmental stages and still under test, the locomotive is being used alongside other forms of motive power in regular freight service by the Union Pacific Railroad.

A similar unit, rated 3500-kW, geared to a standard 3600-rpm generator and operated with natural-gas fuel, was placed in operation by the Oklahoma Gas and Electric Company, Oklahoma City, in July, 1949. This was the first gas turbine-generator unit to be operated by a power company in the United States and has to date produced more than 26-million kW-hrs.

Another 3500-kW simple-cycle gas turbine was put on the line in April of this year by a New England power company. A 5000-kW two-shaft compound-cycle unit, with intercooling and regeneration, is being installed by G.E. for another New England utility concern.

IRONFOUNDERS CONFERENCE

A conference of great importance to ironfounders is being held in London on Wednesday and Thursday (September 20 and 21) by the Joint Iron Council in conjunction with the Council of Ironfoundry Associations. It has been convened for consideration of the report of the Grey Ironfounders' Productivity Team which, under the auspices of the Anglo-American Council on Productivity with Marshall Aid, visited the U.S. early this year.

The leading members of the Grey Iron Founders' Society of

CASTING SERVICE

IMMEDIATE CAPACITY AVAILABLE WITH MODERN FOUNDRIES PATTERN SHOPS AND STAFF OF SKILLED TECHNICIANS

From Drawing Office to Machine Shop your casting jobs are carried out by skilled experts — under complete technical control.

Engineers' Grey Iron Castings from 1 lb to 2 tons to your entire satisfaction. **Ample capacity available for Pattern Making.**

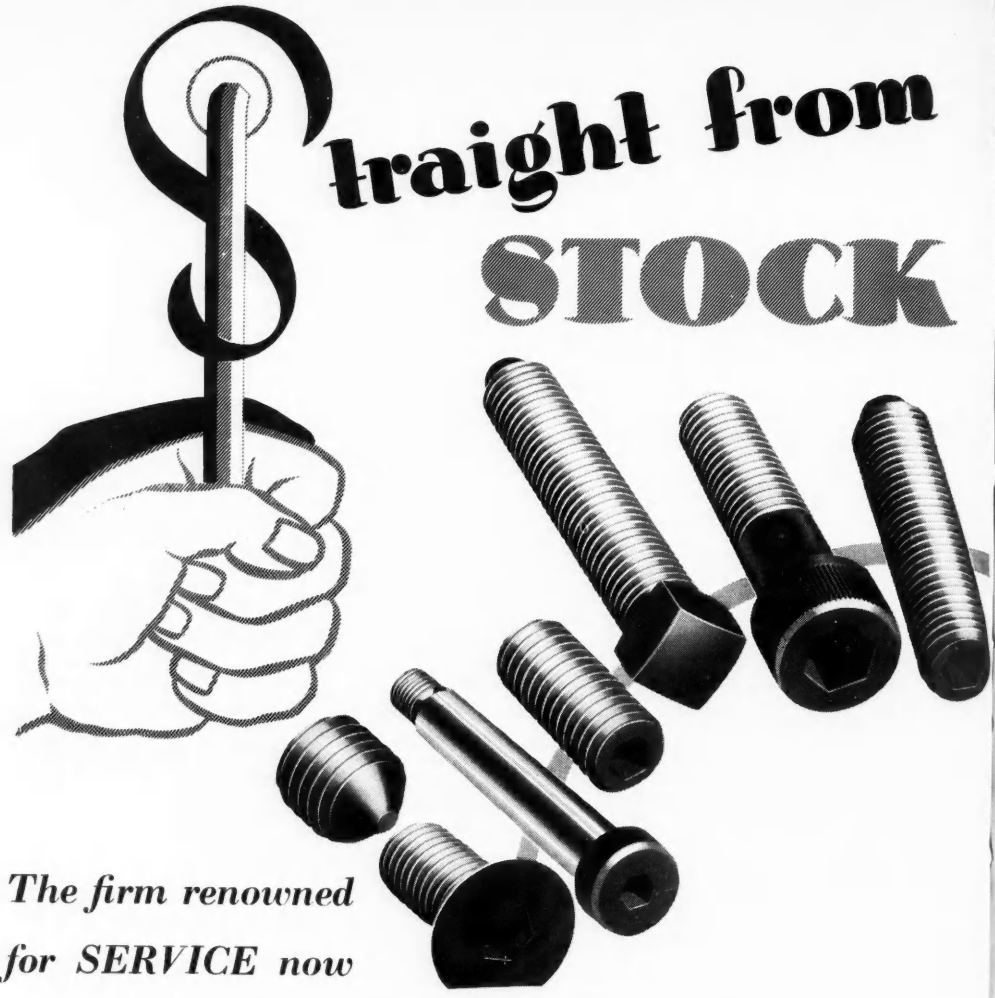
● **Quick delivery.** Road Transport 50 Mile Radius ●

Send us your patterns or drawings and get our quotation

The Alliance Foundry CO. LTD.

ICKNIELD ROAD WORKS. LUTON. BEDS. 'Phone-LUTON 1231

Straight from STOCK



The firm renowned for SERVICE now offers the most comprehensive range of

"UNBRAKO"

HIGH TENSILE SOCKET SCREWS

London Office: 295 EUSTON ROAD, LONDON, N.W.1

Phone: EUSton 5311 (3 lines). *Telegrams:* EMANCEE, LONDON

Ring CALTHORPE 3177 (3 LINES)

MONKS & CRANE LTD · STANHOPE ST · BIRMINGHAM · 12

The Twist Drill Specialists!

Cleveland, Ohio, which largely organized the tour in the U.S., are, with the assistance of E.C.A., coming specially to London to attend the conference—Mr. H. P. Good, the president, and Mr. Raymond L. Collier, executive vice-president. The leaders of the two other foundry teams which have visited the U.S., Mr. F. A Martin (Steel Founders) and Mr. F. Hudson (Brass Founders) have been invited and the members of the Ironfounders' team will also be present.

The report, which is larger than any so far issued by the A.A.C.P. will be discussed in all its aspects from the employers' point of view. It analyses fully the reasons for greater productivity in U.S.A. and the problems facing the British industry, and contains far reaching findings for the consideration of the 2,000 iron foundries in this country. A later section gives a full and well illustrated description of what the Team saw in American foundries.

GALVANIZERS TO VISIT U.S.A.

The next team to visit the U.S.A. under the auspices of the Anglo-American Council on Productivity with Marshall Aid is a Specialist Team on Galvanizing, which left in the "Queen Elizabeth" Thursday, September 14th, and will return from New York in the "Queen Mary" on October 31st.

It has been decided to send a Specialist Team instead of the normally constituted Productivity Team representing management, technicians and operatives because galvanizing as such is not really a separate industry in this country—though there are plants which specialise in it—but rather one process in a large number of manufactures, and the main need is a survey by specialists of galvanizing techniques in the U.S.A.

The Trades Union Congress has, however, nominated two members of the team, which will number 15. The Leader is Mr. Frederick C. Braby, Chairman and Managing Director of Frederick Braby & Co., and Chairman of the Hot Dip Galvanizers Association. The other members are representative of all types of galvanizing in this country, including that of tanks, hollowware, windows, marine equipment, and nuts, bolts and small parts. In the last few weeks they have been inspecting British plants.

The American Hot Dip Galvanizers Association is taking great interest in the visit and the plants of several of its member firms will be inspected, as well as other plants, so that the covering of processes and of works of varying size may be fully representative. Hand and mechanical dipping and the continuous process will be studied and particular attention will be paid to general research on galvanizing and research on the corrosion of galvanized coatings.

PUBLIC WORKS AND MUNICIPAL SERVICES CONGRESS AND EXHIBITION, 1950

Local authorities in Great Britain have already appointed over 900 delegates to attend the Public Works and Municipal Services Exhibition and Congress which are to be held at Olympia, London, from November 13 to 18. Exhibitors number 250 and include the Ministry of Agriculture and Fisheries and the Department of Scientific and Industrial Research.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.1)

B.S.G. 127 "Power Transformers for Aircraft," applicable to transformers and auto-transformers used in aircraft for supplying power from the aircraft main A.C. supply, the transformers being rated from 500 VA upwards. The aircraft A.C. supply may be in one of two forms—voltage varying with frequency so that the ratio of volts to frequency remains substantially constant, or constant voltage with variable frequency. Price 2/–.

B.S.G. 126 "Electric Power Metal Rectifiers for Aircraft," detailing the requirements for rectifier equipment, rectifier stack assemblies, and rectifier stacks, for rectifying aircraft main and auxiliary A.C. power supplies to D.C. Price 1/–.

B.A. Washers for Aircraft Purposes. B.S. SP. 22-27 : 1950 apply to washers primarily intended for use with screws (2 B.A. and smaller) used in aircraft instruments, and in electrical and similar equipment for aircraft. The washers are identical with those covered by the revision of B.S. 57—"B.A. bolts, screws, nuts and washers," now in course of preparation, with the exception of provisions relating to protective treatment and identification. Price 1/–.

Steel Filler Rods for Gas Welding of Mild Steel. B.S. 1453 : 1950 covers rods for applications in which a minimum butt weld strength of 28 tons per sq. in. is required and supersedes a tentative specification produced as Appendix A to B.S. 693 : 1940—Oxy-acetylene welding in mild steel. It does not cover steel rods for general weding purposes.

The rod is specified in terms of chemical composition and emphasis is laid on the ratio of the carbon to manganese. Other clauses deal with size and tolerances, condition of supply and provision is made for the issue of a certificate of compliance with the specification. Price 1/–.

Circular Screwing Dies and Hexagon Die Nuts, B.S. 1127 : 1950. The first British Standard for Circular screwing dies and hexagon die nuts was issued in 1943 as a War Emergency Standard, when its primary object was to bring about a simplification in the variety of outside diameters of circular screwing dies. Provision was made for nine outside diameters of circular dies, applicable to all sizes of thread up to 2 in. B.S. Pipe (Parallel) thread, any particular thread being associated with not more than three diameters of die.

After review in the light of present day conditions it has now been adopted as a British Standard and is issued in the form of a revision to permit the addition of dimensions for a comprehensive range of hexagon die nuts for all sizes of thread up to 4 in. B.S. Pipe (Parallel) thread. Price 1/–.

Friction Surface Rubber Transmission Belting, B.S. 351 : 1950. The document provides four fabric weights for use in the construction of belting, and gives full constructional details and test requirements.

It also incorporates appendices dealing with service conditions. Price 2/–.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

ADMIRALTY (Civil Engineer-in-Chief's Department)

Vacancies exist for Architectural and Civil Engineering Assistants in the Drawing Offices at H.M. Dockyards and Establishments at Home and Abroad.

Applicants must be competent draughtsmen and designers with experience in some of the following types of Building and Civil Engineering Structures and Works :—

Structural Steelwork, Reinforced Concrete, Dock and Harbour Works, Accommodation, Residential, Office, Store and Factory Buildings, Oil Fuel Tanks and Pipe Lines, Airfield Construction and Maintenance, Rail, Road, Water, Sewerage and Heating Services, etc.

The salary range for Architectural and Civil Engineering Assistants is £300-£525 p.a. (consolidated London Rate) subject to Provincial Differentiation of £20 at the minimum and £30 at the maximum. The minimum is tied to age 21 with an increase (or deduction) of £20 for each year over (or under) the age of 21 up to a maximum, on entry, of 7 increases. In addition, appropriate rates of Foreign Service Allowance are payable at Stations abroad.

There are vacancies immediately existing at Pinner, Chatham, Fareham, Portland, Liverpool, Broughton Moor (Carlisle), Invergordon, Milltown (Elgin), Rosyth, Glasgow, Devonport, N. Ireland (Belfast or Londonderry) ; in addition vacancies periodically occur overseas.

The Appointments are temporary.

Applications should be made, giving full particulars of experience, to The Civil Engineer-in-Chief, Admiralty, Chamberlain Way, Pinner, Middlesex.

WANTED

BACK ISSUES OF THE ENGINEERS' DIGEST Wanted. Copies of the January and June, 1950, issues at 3/6 per copy. Double the original price, 9/– per copy offered for copies of the August, 1940, issue.—Send copies to the SUBSCRIPTION DEPARTMENT, "THE ENGINEERS' DIGEST," 120 Wigmore Street, London, W.1.

WORK WANTED

CASTINGS.—A small amount of immediate available capacity for precision aluminium gravity die castings, zinc pressure die castings.—Write or 'phone **Thos. Ashworth & Co., Ltd.** (Dept. A/15/9), Vulcan Works, Burnley, Lancs. (Burnley 3505).

TRANSLATIONS, Abstracts. German, French, by Engineer, long resident abroad. Priest, 50, Sion Road, Bristol, 3.

FOR SALE

NISSEN TYPE HUTS, ex-Government stock, reconditioned and supplied ready for erection. All sizes in 6 ft. multiples. 36 ft. by 16 ft., £65 & £54 ; 24 ft. by 16 ft., £46 & £38 ; 72 ft. by 16 ft., £122 & £97 ; delivered U.K. Plasterboard huts and other buildings. Some 24 ft. span Nissens.—Write, call or telephone, **Universal Supplies (Belvedere) Ltd.,** Dept. 50, Crabtree Manorway, Belvedere, Kent. Telephone No. ERITH 2948.

FOR SALE—NEW 100 K.V.A. ALPHA-HARRIS ALTERNATOR, complete with exciter, type G. 400, voltage 440/220, speed 1,000 r.p.m., 50 cycles, 4 wire, 3 phase, £700.—Norths, 94, Vicar Lane, Leeds. Phone : 26249.

LATEST INDUSTRIAL LITERATURE

1. British-built Vertical Broaching Machines. Two illustrated leaflets giving design details of a range of vertical broaching machines. One of the leaflets describes a single-ram variable speed hydraulic surface broaching machine which is available in various sizes up to 25-ton capacity and 90-in. stroke. The second leaflet deals with a double-ram machine, built in standard sizes up to 32-ton capacity and 66-in. stroke.

2. Oxygen Cutting and Profiling Machines. Well designed and profoundly illustrated 26-page brochure presenting a brief and concise outline of the development of modern oxygen profiling. Containing sufficient information to assess the scope offered by this method of shaping steel, the brochure includes many excellent illustrations of the newest oxygen profiling machines.

3. Precision Casting. Designers of machinery, tools, instruments and parts will enjoy perusing this cleverly designed and nicely produced 24-page brochure, one of the first published on this process in Gt. Britain. It presents a little history of precision castings, describes the process of manufacture, lists and illustrates 31 " impossible " jobs and includes composition and properties of suitable alloys.

4. " Cronite " High Temperature Alloy. 28-page brochure giving a general outline of the applications of nickel chromium castings which have been produced for service with prominent engineering companies. In addition to well reproduced illustrations, brief details on machining and welding " Cronite " are given.

5. A New Conception of End Mills. Exceptionally well designed and illustrated folder dealing with an entirely new design of an End Mill and Holder. Two types of End Mill, i.e., 2 flute type and multi-flute type, each having new shape fast helix flutes are described. Increased feeds, greater accuracy of work produced and more cuts per grind are the advantages of these tools the assembly of which within the unique holder affords the operator a much clearer view of the work being produced than is obtained with a normal type of Holder and End Mill.

6. Oval Muffles. Illustrated leaflet describes oval type muffles designed and ideally suited for general heat-treatment of flat dies, small work in shallow pans, etc. Smaller muffles are provided with flap doors, the larger with the counterbalanced pattern.

7. The Mercury-Arc Rectifier. 36-page illustrated technical booklet presents a concise and simple description of the functions and operation of mercury-arc rectifiers. The booklet which is profoundly illustrated should be of benefit to all interested in a converting apparatus where D.C. is required and to engineers who may have to operate it.

8. Clutches and Power Take-Offs. 16-page brochure presents a general indication of the sizes and potentialities of a range of Power Take-Offs and Clutches. Typical applications include tractors, graders, compressors, portable generators, power shovels, cranes, oilfield equipment, materials handling equipment and all types of stationary diesel, paraffin and petrol engines. Excellent illustrations, specifications and installation particulars add to the value of the brochure.

9. Autopositive Contact Document Paper. Leaflet containing particulars of an unusual photographic paper for the production of a direct positive copy with normal processing. Lower production costs, convenience of handling, extra contrast, lightness and permanence of image are the main advantages of this paper.

10. Fractional Horse Power Motors. 8-page illustrated brochure contains full specifications of a range of fractional horse power motors of a new design which offers the advantages of reduced overall dimensions, extreme quietness of running throughout the life of the motor, and a design of centrifugal switch which is completely reliable and has been proved to remain silent even after 800,000 operations.

11. Manograph. Provisional leaflet to introduce a unique, compact instrument for accurate recording of static pressure or differential pressure. The instrument can provide a permanent record in all applications where a manometer is used for the indication of pressure.

12. Recording Thermometers. Illustrated leaflet just issued describes three types of recording thermometers, i.e., the vapour-pressure type (+ 60 deg. F. to 650 deg. F.), the gas filled type (— 100 deg. F. to + 1,000 deg. F.) and the liquid filled type (— 40 deg. F. to + 212 deg. F.).

13. " Britan " Repetition Lathe. 4-page illustrated bulletin describes a multi-tool machine designed to give a much higher rate of production than can be obtained from lathes of a similar type. Parallel and Taper Turning, Knurling, Drilling, Counterboring, Countersinking, Internal and External Threading, Profile Turning, Back Cutting, etc., are all readily performed with the machine in its standard form.

14. Hydraulic Power Cropper. Illustrated leaflet describing a compact, highly efficient cropper for cutting flat mild steel bars up to ½-in. thick and sheet metal, vertically and with negligible burr. Both the cropper blade and the patented pressure foot which holds the material whilst being cut, are hydraulically operated.

15. Aluminium for Overhead Power Transmission. Illustrated folder describes the advantages of steel-cored aluminium conductors which combine the lightness, electrical conductivity and corrosion resistance of aluminium with the strength of high tensile steel.

16. Industrial Battery Chargers. 16-page illustrated booklet covers single circuit, twin and three circuit chargers with full details and specifications. A concise introduction deals with the application of selenium rectifiers to battery chargers to show the function of the rectifier and how it affects the performance of the charging unit. An illustrated description of plating and anodising rectifiers is included.

17. Instrument for Angular Measurement. Illustrated folder describes a precision instrument which has been developed for precise angular measurements required in the manufacture of all high-grade products incorporating gears, cams, splined shafts or notched discs as well as components machined on a circular table or dividing head.

18. Core-binding Resins. Technical leaflet depicts the characteristics of a synthetic resin specially designed for use as a core-binder. The resin hardens on baking to an insoluble and infusible state. The hardening (curing or polymerisation) results from a change in chemical composition under the action of heat, and is not dependent upon oxidation.

19. Strain Gauges. 12-page illustrated catalogue offering a considerable amount of essential information on strain gauge technique. The Resistance Wire Strain Gauge is a very powerful tool for the investigation of both static and dynamic stress problems, and the catalogue contains, in addition to the above information, a list of standard gauge sizes and a list of measuring instruments for use with strain gauges.

20. Low Resistance Dust Collector. Illustrated folder gives detailed information on the construction, principle of operation and advantages of low resistance dust collectors. This collector is essentially for use with small boiler plants with steel chimneys. It is efficient, low in cost and requires minimum of maintenance.

21. Thermostatic Controls. Illustrated folder just issued depicts a range of self-actuating micro switches for temperature control in an increasing number of applications. These controls are extensively used by the motor industry. Recent applications include the temperature control of electrically heated aircraft oil tanks and pipes; fire detection for aircraft engines; protection against fan failure on mercury arc rectifiers; built-in warning indicators for oil cooled transformers, etc. One recently developed special switch controls the mixing temperatures of hot and cold liquids to a very small control differential, irrespective of pressures and temperatures.

22. " Escaloy " New Standard Tools. 48-page catalogue, with neat and excellent illustrations, covers the simplified range of Cemented Carbide Tools, including the new standard tools. These new tools and tips have been carefully designed to cater for all normal production work and wherever possible, maximum life and cutting efficiency have been improved. Up-to-date technical data for guidance in the correct care and application of the new tools are included in the catalogue.

23. Independent Lathe Chucks. 12-page illustrated brochure describes a full range of both contrate geared scroll and independent types of lathe chucks. Details of construction, principal dimensions and specifications are given for all types.

24. Heat Exchangers and Condensers. Illustrated leaflet describes the Rosenblad design of Spiral Plate Heat Exchanger of three types, i.e., for transfer of heat between two liquids; for condensing vapour where only a small pressure drop is allowed, and for the recovery of heat from vapour-gas mixtures. Data relating to eight typical spiral plate heat exchanger installations are included.

MAIL THIS COUPON TODAY

THE ENGINEERS' DIGEST, IX.58
120, Wigmore Street, London, W.1.

Date.....

Please send free and without obligation the literature indicated by the following circled numbers :

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24

Name .....

Position .....

Company.....

Address .....

THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *VACUUM LEAK DETECTOR*

The locating and repairing of leaks in vacuum systems is probably the most troublesome aspect of high-vacuum technique. Of the various types of leak detectors in common use, the recently developed helium leak detector appears to be especially suitable for the rapid location of vacuum leaks. This instrument incorporates a small-radius spectrometer using a cold cathode ion source for the production of positive ions and cathode-ray scanning for a detector. In locating a leak, it is convenient to use a hood which is placed over the spot where a leak is suspected, and the interior of the hood is then flooded with helium, which will seep through the leak into the vacuum system, where its presence is then detected. A commercially available instrument of this type is claimed to respond to leak rates from the atmosphere into an evacuated system as low as 10^{-9} cubic centimetres per second. Instruments based on this principle could be set for gases other than helium, but this is used because it rapidly diffuses into a leak and cannot explode or catch fire.

● *PUMPS WITHOUT STUFFING BOXES*

The radical method of eliminating stuffing-box leakage in a centrifugal pump is to eliminate the stuffing box altogether, and at least one American pump maker has taken this step. In this particular design, stuffing boxes are got rid of by providing the pump with a small secondary impeller which deals with the leakage. When the pump is slowing down or is stopped altogether, a governor-operated seal closes the space between the pump casing and the shaft. Another firm of pump makers eliminates stuffing boxes in their submersible deep-well pumps by using a mercury seal* which isolates an oil-filled motor from the pump. The employment of pumps with mercury seals is, however, restricted to cases where the liquid to be pumped will not sludge with mercury. In order to overcome this and other inherent limitations of the mercury seal, the same firm of pump makers has developed a double mechanical seal, which, in the submersible pump, isolates the pump from its motor. The motor chamber is filled with an electric motor oil of good dielectric characteristics and put under slightly greater hydraulic pressure than exists at the pump suction. Any slight leakage of the mechanical seal will, therefore, take place from the motor to the pump. A balance chamber with metal or synthetic rubber bellows provides for the thermal expansion of the oil. It is reported that the basic principle of this pump has been applied to numerous special cases, as, for instance, the construction of a stuffing-boxless pump for use with pure water at 1000° F and 5000 psi pressure.

* A previous reference to mercury seals will be found in the Blue Pages of our July issue, page 231.

● *PRODUCING CERAMIC COATINGS BY ELECTROPHORESIS*

Electrophoresis, that is, the enforced undirectional movement of particles in a liquid by means of an electric current, can be used to effect the deposition of mineral compounds on a metal surface. A recent British Patent Specification describes the manner in which this phenomenon can be exploited for producing electrically insulating layers on metal surfaces. To carry out the process, use is made of a bath consisting of an aqueous suspension of finely divided bentonite or bentonitic clay. Since the particles contained in the suspension have negative electric charges, they can be deposited on the metal surface to be covered by connecting the immersed piece to the positive pole of a source of direct current, the other pole being constituted by a metallic electrode, also immersed in the solution. Potential differences varying between 1 and 30 volts are used. The thickness of the layer produced may be made to range from one-thousandth millimetre to one millimetre or more, depending upon process conditions and length of treatment. Prior to processing, the part to be coated must be cleaned so as to remove any traces of oil or grease. When the coating has been formed, the part is oven-dried and then baked at high temperature, with the result that the coating becomes very hard and tenaciously adheres to the coated surface.

● *SELF-CENTRING CONVEYOR ROLL*

The ingenious application of a very simple kinematic principle has resulted in the development of a novel self-centring conveyor roll. Fundamentally, this self-centring roll is a slightly crowned roll cut transversely at the centre. The two halves are made to rotate as a unit, with the roll axes set at such an angle as to

We have pleasure in introducing a new development in Firth Brown "Mitia" Carbide.

Our aim—a carbide which would appreciably widen the range of machining operations covered by one grade, giving improved performance with the attraction of minimising the stocking of varying grades.

Our achievement—an outstanding combination of toughness and resistance to abrasion—the perfect general-purpose grade for the machining of steel.

All ferrous machining operations from the heaviest of intermittent cutting to the finest light finishing now covered by THREE GRADES OF "MITIA"—

T.A.5
MAUVE LABEL

For heavy duty rough machining under poor conditions. For intermittent cutting at relatively low speeds and heavy feeds.

T.T.A
DOUBLE T.A.
YELLOW LABEL

A general-purpose grade for machining all classes of steel under reasonably good machining conditions. Combines high resistance to abrasion with excellent toughness and can be applied over a wide range of machining conditions.

T.E.
GREY LABEL

Extemely hard and wear resistant. Designed for finish turning all classes of steel under good machining conditions. Very high speeds with fine feeds will give the best results.

F. B
FIRTH BROWN
TOOLS LTD. SHEFFIELD

make the upper working faces of the rolls approximately horizontal. In this way, the planes, or rather lines, of force in both halves twist evenly towards the centre in the direction of movement, thus conferring a self-centring action on any material passing over the rolls. It is claimed that this principle finally solves the problem of self-centring power belts, conveyor belts or materials conveyed on roller tables without side guides. It has been found that a crown deviation of as little as one-hundredth of an inch from the horizontal is sufficient in a split roll to create the self-centring action. Rolls of this type have already been tested for a diversity of applications, such as run-out tables, feed and guide rolls for electrolytic tinning, galvanizing and pickling lines, gravity conveyors, belt pulleys and conveyors and similar applications in the steel industry.

● *HOME-MADE BALL BEARING*

There should exist numerous opportunities in mass production technique where the inherent advantages of ball bearings can be secured by comparatively simple home-made designs, provided conditions do not call for precision-made bearings of high performance. In a typical case, important savings in manufacturing cost could be achieved by equipping a television antenna rotator and holder with a ball bearing which is made up of a steel band and hardened steel balls mounted in a diecast aluminium base. An outstanding feature of this design is the small amount of machining required, the ball-races and the bearing retainer ring being cast within dimensional limits. The ball-races are machined to a total dimensional tolerance of 0·005 in. A steel band clamped around the diameter of the base with evenly spaced spring steel clips placed at right angles holds the balls in the ball-races. Diecastings were selected in this instance after careful consideration of alternative means of fabrication, including sand and permanent mould castings and stampings. Cost comparisons showed the diecasting to be the most economical.

● *INTERNAL COOLING OF CENTRIFUGAL COMPRESSORS*

The advantages resulting from the cooling of a gas during compression are well known. Usually, this cooling is obtained by withdrawing the gas from the machine at one or several intermediate points between compression stages, and passing it through surface coolers. It has recently been demonstrated that, without much added expense, the gas may be cooled as it passes through the fixed passages of a centrifugal compressor. Because of the high velocity of the gas in these passages, high rates of heat transfer from the gas to the cooling water can be obtained. Perhaps the most important conclusion to be drawn is that internal cooling makes possible low-cost, compact, multi-stage centrifugal machines for compression to relatively high pressure. In the past it has been general practice to employ air-compressor casings of only four or five stages, since more stages within one casing would involve gas temperatures too high for economical compression. Thus, the average 100-psi compressor consists of two casings plus intercooler. Based on this new knowledge, such an arrangement with only a small loss in operating efficiency can be reduced to a compact single casing containing all the stages without any external cooling.

● *THERMAL CONDUCTIVITY OF STEAM*

Accurate knowledge of the thermal conductivity of steam is a matter of great practical importance, since, in the computation of heat transfer coefficients for steam, the factor of thermal conductivity is included in the basic formulae. This applies, in particular, to cases where calculations must be made for steam pressures and temperatures regarding which no test data are extant for the type of equipment contemplated. Unfortunately, the experimental determination of the thermal conductivity of steam meets with formidable obstacles which are extremely difficult to overcome. These difficulties are of a fundamental nature and are bound up with the strong energy radiation absorption and emission characteristics of steam, which make it difficult to interpret apparent thermal conductivities as found by experiment. It will, therefore, be a matter of considerable satisfaction to steam equipment designers that new data of satisfactory accuracy have now become available which represent a very great advance over older data, some of which have long been known to be of most doubtful value.

● *NEW PRINCIPLE IN ARC INTERRUPTION*

Many schemes have been developed through the years to improve the performance of low-voltage contactors by reducing arcing time. The conventional method has been that of placing the arc in a strong transverse magnetic field set up by the load current passing through a blow-out coil. In the course of a search for an improved contactor design, a new type of arc chute has been developed which reduces the arcing time. It is claimed that through the resultant reduction in peak arc current, vaporisation of contact surface material is lessened considerably, and contact operating life is expected to be much greater. In the new device, the rising arc impinges in succession upon a number of arcing segments of metal which act to cool the arc path and play the rôle of individual blow-out coils. The individual, somewhat U-shaped, segments are insulated from each other and are placed at right angles to the circumference of contact travel. When the arc reaches the main

"airflo"

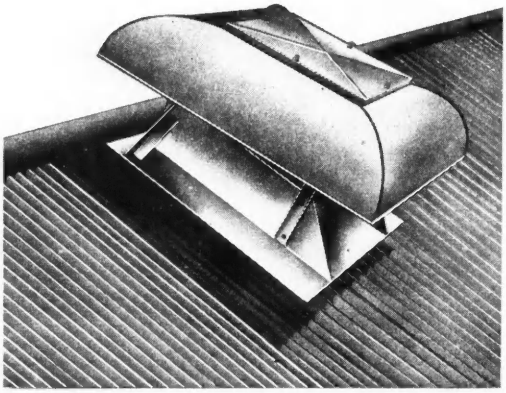
FAN POWERED VENTILATOR

EASILY FITTED TO ANY ROOF

18″ FAN — STANDARD SUPPLY 400 V. 3 ph. 50~. — 3900 cfm

£26 EX WORKS

Subject to current raw material prices.



ALUMINIUM BODY—COMPLETELY WEATHERPROOF

Full Particulars on Request

DUST FUME AIR CONDITIONING
VENTILATING PLANTS.

INDUSTRIAL FAN & HEATER COMPANY LIMITED.

ANNE ROAD · HANDSWORTH
BIRMINGHAM 21.

Telegrams: AIRFLO. **Telephone: SMETHWICK 1545/6.**

Northern Area
22 CITY BUILDINGS, 69 CORPORATION ST., MANCHESTER 4

Telephone: BLACKFRIARS 6918

Technical Books

Just Published

THERMODYNAMICS

A Modern Introduction to General Thermo-dynamics and its applications to Chemistry and Physics.

by J. R. PARTINGTON, M.B.E., D.SC.

Demy 8vo. **22s. 6d net**

Just Published

MICRO-WAVE MEASUREMENTS

by H. M. BARLOW, B.SC. (ENG.), *and* A. L. CULLEN, B.SC. (ENG.)

400 pages. 214 figures. **30s. net**

TRANSFORMATION CALCULUS AND ELECTRICAL TRANSIENTS

By S. GOLDMAN, Ph.D.

Demy 8vo. 439 pages. Illustrated.
30s. net

HEAT PUMPS AND THERMAL COMPRESSORS

(Four Lectures delivered at King's College, London)

By S. J. DAVIES, D.Sc., Ph.D.

Cr. 8vo. Illustrated.
9s. net

REFRIGERATION AND AIR CONDITIONING

By R. C. JORDAN *and* G. B. PRIESTER.

Med. 8vo. 512 pp. Illustrated.
30s. net

CONSTABLE & CO. LTD.

10 ORANGE STREET - LONDON, W.C.2

and from all booksellers

blow-out zone, all units are in operation. It was observed that with the new blow-out device, the very minimum of arc gases was produced, indicating interruption in air rather than in a metallic vapour cloud.

● *FORMING TANKS BY HYDRAULIC PRESSURE*

The shaping of metal parts by the spinning of sheet metal very frequently provides the solution to the problem of achieving minimum production cost. There are, however, limitations to the applicability of spinning, and in one particularly interesting instance the exigencies of cost reduction led to the development of an entirely novel manufacturing technique. This particular case was concerned with the manufacture of aluminium tanks for aircraft. Several experimental tanks were made by spinning, but this method proved too costly for production use. In the method evolved, tank halves are preformed on a drop hammer and then joined by welding, followed by heat treatment. In order to make the dimensions of the tank comply with the tolerance required on the overall contour, forming by hydraulic pressure is employed. A large sizing die or cavity was made, which was capable of withstanding 500 psi internal pressure. After welding and heat-treatment, the tanks are placed inside the sizing die and hydraulic fluid is pumped into a rubber bag placed inside the tank to force the tank walls against the die. Time required for the final sizing operation was found to be only 3 minutes, this being merely the time required to pump in the required quantity of fluid and drain it out again.

● *HEAT-TREATMENT OF ALUMINIUM PRESSURE DIECASTINGS*

A data sheet on the heat-treatment of aluminium alloy castings issued by a technical association of light alloy refiners refers to the fact that pressure diecastings have commonly greater mechanical strength than castings produced in sand moulds, and it might be expected that this superiority in strength could be further increased by heat-treatment as it can with gravity diecastings. Unfortunately, however, the solution heat-treatment of pressure diecastings introduces a problem which does not arise in the case of sand or gravity diecastings, and which renders the full heat-treatment of almost all commercially produced pressure diecastings impossible. Almost all pressure diecastings contain bubbles either of air or gas from the lubricant, and if very small and well dispersed, these bubbles do not affect the strength of the casting. These bubbles are entrapped by the rapidly moving and turbulent stream of metal injected into the die, and the gas is retained under the diecasting pressure as the casting solidifies. When the pressure diecasting is heated to the solution heat-treatment temperature, the pressure in the bubble increases and the strength of the metal falls. As a result, the castings become distorted and "pimples" appear on the surface. Precipitation treatment does not produce these undesirable effects and a marked increase in strength and hardness is produced by it, without a previous solution treatment, with alloys which are usually fully heat-treated. This is possible because the rapid chilling obtained by pressure diecasting, to some extent, is similar in effect to the quench following solution heat-treatment.

● *REFRACTORY LINER FOR CYLINDERS*

It has been proposed from time to time to provide the cylinders of internal combustion engines with liners of fused silicate, quartz or porcelain. These suggestions, however, have met with no success in practice, principally because of the cracking of the refractory liner by the shock of the explosion wave. A recent proposal envisages the use of a liner of a sintered refractory material of great hardness with a steel sleeve shrunk onto the liner so as to put the latter under approximately 30,000 psi tangential compressive stress. In order to test the effectiveness of this arrangement, a liner of sintered alumina was subjected to local internal heating by an oxygas flame, but, in spite of the highly localised and asymmetric heating, no cracking occurred. A further important claim is that metal pistons and metal piston rings sliding on such a refractory liner are worn very much less than on cast iron or steel. The explanation given is the reduced tendency for seizure and scoring to take place, and the fact that hard dust particles cannot become embedded in the still harder refractory liner, but are swept away before they can cause abrasion of piston and rings.

● *NEW IMPACT TESTER FOR BOTTLES AND JARS*

A new pendulum-type impact tester for glass bottles and jars has been developed, which, it is claimed, avoids most of the shortcomings of existing impact testers and comes as near as practicable to simulating service impacts, while at the same time giving reliable data on strength. The pendulum striker is employed because of its simplicity and ease of calibration. Two scales are provided, one is graduated in inch-pounds of energy available, and the other in inches-per-second velocity of the striking head at the instant of contact. The pendulum weighs 1·35 lb, which is comparable to the weight of an average bottle filled with its contents. It is believed that most bottles are broken by impact on another bottle, that is, by the collision of two objects of equal mass. The forces of impact are affected by the relative masses, and this has to be taken into account when the bottle is supported by a back-stop. "Back-stops" are usual when,

CLOSER INSPECTION of Steel Welds

WHEN you come to look into it, the use of the right ILFORD Industrial X-ray film is just another way of achieving a closer degree of inspection without any extra cost. ILFORD Industrial X-ray films are manufactured in a range that enables the maximum contrast and resolution to be obtained for any particular power of installation and type of subject. The radiography of welds usually calls for an emulsion of high contrast and high speed coupled with medium grain which are to be found in the highest degree in ILFORD Industrial X-ray film Type B which can be used with or without metal screens.

Full particulars of all ILFORD Industrial X-ray films, screens and exposure techniques for all classes of work are given in the Ilford book, "Ilford X-ray Films and Screens for Industrial Radiography"—free on request.

ILFORD **X-ray Films and Screens for Industrial Radiography**

ILFORD LIMITED · LFORD · LONDON

Take a tank wagon...

and see the many points in its construction where aluminium alloys can be used with increased efficiency and economy.

Our Technical and Development Departments have done a vast amount of research on this subject, and the results are freely available to rolling-stock designers and builders.

Aluminium alloys have equally important uses in many other industries and information about them is at the disposal of all who are interested. The Metals Division of I.C.I. produces a wide range of aluminium alloys in sheet, strip, tubes, extruded rods and sections. Some of them might be useful to *you*. Please tell us your problems.

In the railway industry I.C.I. aluminium alloys are recommended for:—

Supporting structures · Tanks · Buffers · Wheel centres · Roofing and panelling · Sliding and folding doors · General small fittings

'KYNAL' AND 'KYNALCORE' ALUMINIUM ALLOYS

IMPERIAL CHEMICAL INDUSTRIES LIMITED, LONDON, S.W.1

M.170a

for instance, bottles on a filling line collide with one another. The new machine uses a back-stop which is several times the weight of any ordinary bottle and is firmly mounted on a flexible post so that it has some freedom to move away from every blow. The height at which the blow is delivered against the bottle is adjustable.

● *STRESS CORROSION OF POLYETHYLENE*

The expanding and varied industrial applications of polyethylene call for a thorough understanding of the measurement and interpretation of the mechanical properties of this material. As polyethylene is a relatively new thermoplastic, its suitability for different applications has not yet been well established. In many ways, polyethylene resembles a soft non-ferrous metal having a non-linear stress curve and great ductility. This ductility and the low modulus of elasticity of polyethylene have frequently led to its classification, erroneously, as a rubber-like substance. Cognizance must be taken of the fact that polyethylene has some degree of crystallinity and, in common with metals, is susceptible to stress-cracking or stress-corrosion. A recent report contains important information on the effects of some environments upon the properties of polyethylene. It is found that tensile specimens containing a small hole break at stresses and elongations less than those normally reported. This change in mechanical properties is greatly accentuated by fluids such as alcohols and toluene. This phenomenon is comparable to stress-corrosion cracking of metals in mildly corrosive environments. The report gives data for a wide range of molecular weights of polyethylene resins, and the effects of environment are found to decrease with increasing molecular weight of the resin.

● *ULTRA-HIGH-SPEED CAMERA*

The experimental study of the shock and detonation accompanying explosive reactions has hitherto been hampered by the lack of ultra-high-speed instrumentation. Short-duration optical studies are especially necessary for investigating self-luminous detonations and shock waves. The velocity of these transients averages about 8 mm per micro-second, and photographic exposures of these transients must not, therefore, exceed 10^{-7} seconds. In order to overcome the shortcomings of existing methods, an American investigator undertook to build a motion picture camera capable of obtaining 300 successive 4×4 inch frames at rates which can be varied from 10^5 to 10^9 frames per second. In this camera, a multi-slit focal plane shutter is used, which is transported optically across the film plane by a rotating mirror. Each individual frame is composed of a series of lines, and the degree of discontinuity across each frame is proportional to the total number of frames. Since the continuous motion of the image across the film does not form the well-defined frames of the intermittent or the rotating prism type of camera, the resulting picture will be an indistinguishable jumble. However, by proper positioning of the grid over them, any of the individual exposures can be studied separately.

● *CAPACITY DYNALOG*

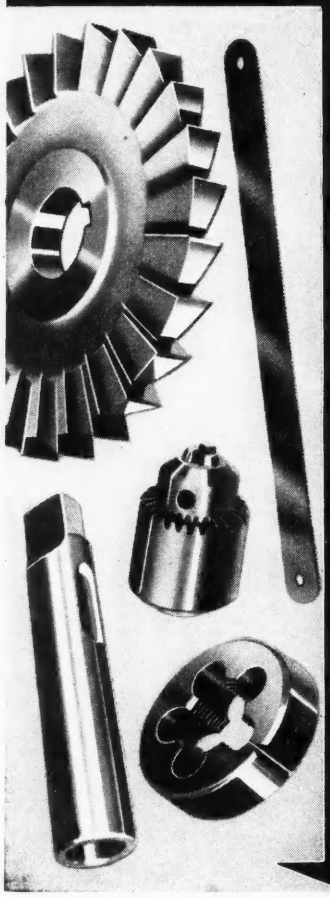
Because of the relative ease with which highly accurate electrical measurements can be made, it is common practice in process control instrumentation to employ means by which the variable to measured is converted into an electrical quantity, such as voltage or resistance change, which then constitutes an indirect measure of the process variable. The measurement of capacitance changes has hitherto been used comparatively little in this connection, but an instrument called " capacity dynalog," which should facilitate the employment of this principle, has now become commercially available. This instrument incorporates the self-balancing principle, but a solenoid type of servo-motor is used instead of the usual rotary servo-motor, while the place of the customary slidewire is taken by a balancing capacitor. An instrument of this type may be used to determine, for instance, the composition of a two-component liquid mixture, measure the moisture content of a solid or its thickness, and measure small displacements, liquid level, and many other variables encountered in process control problems.

● *BARIUM TITANATE TRANSDUCERS*

In the development of ultrasonics technique as an industrial and scientific tool, which is now making rapid progress, barium titanate is beginning to play an important rôle as piezo-electric material for the transducer element which generates the ultrasonic vibrations. This material appears to have important advantages over quartz and Rochelle salt. The polycrystalline nature of barium titanate, which is a ceramic material, makes it possible to mould it into any shape and make it into relatively large pieces. This material is capable of converting a large amount of power per unit area into ultrasonic vibrations, and it may be used in the same frequency range as the usual piezo-electric devices. After manufacture, the barium titanate element must be pre-polarized by an electric treatment somewhat analogous to the magnetization of a permanent magnet. It retains the piezo-electric properties permanently, provided it is not heated much above the boiling point of water.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

EX STOCK DELIVERIES OF REGULAR LINES



TWIST DRILLS
MILLING CUTTERS
REAMERS
SOCKET SCREWS
TAPS AND DIES
SLITTING SAWS
SIDE CHIP SAWS
SANDING DISCS
HACK SAW BLADES
TOOL BITS
LATHE TOOLS
- - FILES - -
SLEEVES AND SOCKETS
ADJUSTABLE REAMERS
LATHE CHUCKS
BROACHES
DIE STOCKS
DRILL CHUCKS
MACHINE VICES
REVOLVING CENTRES

Stockists of "DORMER", "E.S.C.—V.A.P.", "CARDINAL", "QUALCUT", "DOUBLE-MUSHET", "GOLDEN ARROW", "SPEEDICUT", "CAPITOL", "WARRIOR", "WHIRLWIND", "UNBRAKO", "ARCHER", "JACOB", "ECLIPSE", "DING DONG", "TOLEDO", etc.

MONKS & CRANE LTD

THE TWIST DRILL SPECIALISTS

HEAD OFFICE · STANHOPE STREET · BIRMINGHAM 12
Telephone: CALthorpe 3177 (3 lines) Telegrams: Emancee, Birmingham
LONDON OFFICE: 295 EUSTON ROAD, LONDON, N.W.1
Telephone: EUSton 5311 (3 lines) Telegrams: Emancee, London